INSTRUCTION MANUAL

MODEL RS320-1.5B

SILICON RACK SERIES

TRYGON® ELECTRONICS, INC.
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Roosevelt, New York 11575

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NOTICE

This Instruction Manual provides general characteristics, operating procedures, theory of operation, maintenance and calibration procedures and includes a complete schematic, troubleshooting guide and parts list pages for the model(s) listed on the front cover.

Any questions concerning this documentation should be directed to the Publications Dept., Trygon Electronics Inc., Roosevelt, N. Y. 11575.

Questions concerning the operation and application of Trygon power supplies should be directed to the Applications Engineering Dept., at the above address.

MEASUREMENT OF REGULATION AND RIPPLE

The specifications cited herein for regulation and ripple can be readily attained on every Trygon power supply, provided the proper method of measurement is employed. The major consideration is that the highly stable meter and oscilloscope, specified in the calibration section test procedures, must be connected to the sensing terminals and not at the load terminals. The reason for this precaution is that the voltage drop between the load terminals and sensing terminals will yield an inaccurate regulation and ripple measurement.

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SECTION 1
DESCRIPTION

1.1 INTRODUCTION

The Silicon Rack Series power supplies are flexible and dependable sources of DC power which can be used to meet a variety of needs ranging in scope from inspection and production testing, to laboratory bench testing and systems applications.

The wide range of outputs available makes these units well suited for use as basic laboratory power sources. The ability to provide power packaged in minimum space with high reliability meets the demands of most systems requirements.

All components used in the construction of the Silicon Rack units are of the highest quality available, and have been subjected to 100% incoming inspection.

Each electrolytic filter capacitor is of computer grade, and has been quoted by the manufacturer as having a life expectancy exceeding ten (10) years. All semiconductors are silicon for high temperature operation, and permit fully reliable operation at ambient temperatures up to 71°C without any derating, addition of heat sinks or forced air cooling. Each power transistor has been generously "derated" and temperature aged to provide high reliability. All rectifiers are hermetically sealed silicon types, and all zener diodes have been temperature stabilized.

1.2 GENERAL FEATURES

Output, Sensing, Remote Voltage Programming and Remote Current Programming terminals are located on terminal boards mounted on the rear panel of the unit. The power switch, power on indicator light, mode indicator light, current and voltage controls and appropriate metering devices are all located on the front panel. For convenience, additional output terminals have been provided on the front panel.

Constant Voltage Mode

A constant voltage is maintained across the output terminals at any preset value from zero to rated voltage output, provided that the load does not draw more than either the rated output current or more than the preset limiting current value determined by the front panel current control settings.

Constant Current Mode

Constant current operation is achieved by maintaining a constant voltage across an internal current sensing resistor. An automatic crossover network changes the mode of operation from Constant Voltage to Constant Current when the current demand reaches that of the preset current adjust control. The

point at which the operating mode automatically changes is a function of variations in load conditions. The crossover point is adjustable, and can be established anywhere within the current and voltage range of the unit.

Automatic Current Limiting

Short circuit protection is provided by the Automatic Current Limiting circuit which limits the maximum output current under all load conditions. The point at which automatic current limiting occurs is variable, and may be selected anywhere from 1% of the rated current to the full rated current output of the unit. In the event of a short circuit, the output voltage drops to zero and returns to normal only when the short circuit is removed.

Mode Indicator

A front panel mode indicator light indicates when the unit is operating in either the constant current or current limiting mode of operation.

Automatic Overvoltage Protection (Optional Feature)

Automatic Overvoltage (OV) Protection is available as an option wherein special circuitry automatically tracks the programmed output voltage and prevents it from exceeding this output voltage. The voltage differential that will cause the OV to trip is approximately 5% or 1.5 volts above the programmed voltage. An internal sensitivity control is provided to desensitize the overvoltage protection circuit.

Remote Programming

Remote Programming is provided in both the voltage and current modes of operation. Both voltage and current may be remotely programmed over their entire ranges. The scale factor for Remote Voltage Programming is 100 ohms per volt. The Remote Current Programming is approximately determined by computing the value of the programming resistor using the formula $R_{PGM} = 100 \left(1 - \frac{\text{Load Current}}{\text{Rated Current}}\right)$.

1.3 PRECAUTIONARY MEASURES

Wire Size

To assure proper regulation under all load conditions, and to prevent severe distortions of the AC line voltage, it is very important to take into consideration the physical size and current handling capabilities of the input power line. Serious losses in regulation and an increase in ripple may result from underrated or overloaded AC input lines. The maximum AC impedance from the breaker box to the power supply input should not exceed 0.75 ohms.

Voltage Regulator and Inverter Inputs

Do not use voltage regulators or inverters as a primary power source. The outputs of these devices are usually not

sinusoidal in nature, and if used as the AC source for the power supply, will cause serious loss of regulation of the power supply output. Capacitive input filtering used for semiconductor power supplies requires charging to the peak of the rectified AC wave which non-sinusoidal AC sources cannot provide.

Systems Considerations

In systems applications it is recommended that each power supply input power line be run separately to the AC distribution box, in order to minimize cross coupling and interaction between equipment. Do not run sensitive signal leads such as the remote sensing leads in the same cable as the AC input without shielding. To keep the AC ripple in the output to a minimum, it is recommended that the AC input cables should be run in close proximity to the output load cables.

Terminal Post Resistance

All terminals and shorting links serving Outputs, Sensing and Programming must be securely tightened before use. Serious loss of regulation and an increase in ripple can result due to a voltage drop caused by loose terminals and shorting links.

TRANSISTORIZED POWER SUPPLIES

SILICON RACK SERIES

CONSTANT VOLTAGE/CONSTANT CURRENT

RS Series

OUTPUT: 0-20 VDC/0-40 VDC/0-60 VDC/ 0-160 VDC/0-320 VDC

REGULATION, LINE: 0.01% or 3 mv

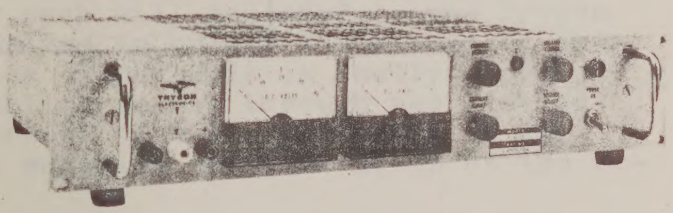
LOAD: 0.01% or 3 mv

RIPPLE: Less than 0.5 mv RMS

INPUT: 105-125 VAC, 55-65 cps

FEATURES

- ALL SILICON DESIGN
- +71°C OPERATION WITHOUT DERATING
- MODE INDICATOR LIGHT
- AUTOMATIC SHORT CIRCUIT PROTECTION
- REMOTE VOLTAGE PROGRAMMING
- REMOTE SENSING
- SERIES OR PARALLEL OPERATION
- NO TURN ON/TURN OFF TRANSIENTS



ELECTRICAL SPECIFICATIONS

CONSTANT VOLTAGE MODE WITH ADJUSTABLE CURRENT LIMITING

Input: 105-125 VAC, 55-65 cps. (200-240 VAC, 50, or 400 cps available).
Output: Floating; isolated from ground, 300 VDC max.
Regulation, Line: 0.01% or 3 mv,* for 105-125 VAC line change at any output without specifications.
Regulation, Load: 0.01% or 3 mv,* no load to full load at any output within specifications.
Ripple: Less than 0.5 mv RMS.
Stability: 0.05% or 18 mv* for 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.
Temperature Coefficient: (0.02% + 400μv)/°C.
High Stability Option (X): 0.01% or 2 mv* with a T.C. of (0.01% + 100μv)/°C.
Temperature Range: −20°C to +71°C†.
Recovery Time: 25 microseconds to recover within 0.05% or 15 mv* of output voltage for 100% step change in rated load.
Short Circuit Protection: Automatic Adjustable Current Limiting (ACL) variable from 1% to 100% of rated current.
AC Power Input Protection: Fuse.
Remote Programming: All units remotely programmable over output voltage range. Scale factor approximately 100 ohms/volt.
Remote Sensing: Maintains rated regulation directly at the load. Maximum line drop 0.5 volts per leg.
Voltage Adjustment Range: Continuously adjustable concentric vernier controls.

CONSTANT CURRENT MODE WITH ADJUSTABLE VOLTAGE LIMITING

Current Range: 1% to rated current output.
Voltage Compliance: 0 to rated output voltage.
Regulation, Line: 0.5% I_{rated} for 105-125 VAC line change at any output within specifications.
Regulation, Load: 0.5% I_{rated} output current change for the maximum change in load resistance within the rated voltage compliance range.
Ripple: 0.25% or 5 ma*.
Stability: 0.5% I_{rated} for 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.
Temperature Coefficient: 0.1% I_{rated}/°C.
Remote Programming: Fully programmable over complete current range. Programming resistance $R_{pgm} = 100\ (1\text{-}I_{load}/I_{rated})$.

*Whichever is greater.
†When stacked without free air circulation temperature should be limited to +60° C.

TABLE 1

Model	OUTPUT Volts	Amps	*Impedance DC-1KC	DIMENSIONS W	H	D	Weight (lbs.)
RS20-7.5A	0-20	0-7.5	0.002	19	3½	14⅝	42
RS20-15A	0-20	0-15	0.001	19	3½	14⅝	47
RS40-5A	0-40	0-5	0.004	19	3½	14⅝	43
RS40-10A	0-40	0-10	0.002	19	3½	14⅝	45
RS60-7.5A	0-60	0-7.5	0.004	19	3½	14⅝	47
RS160-1A	0-160	0-1	0.008	19	3½	14⅝	45
RS160-3A	0-160	0-3	0.005	19	3½	14⅝	49
RS320-1A	0-320	0-1	0.016	19	3½	14⅝	49
RS320-1.5A	0-320	0-1.5	0.020	19	3½	14⅝	49

*Nominal

GENERAL AND PHYSICAL SPECIFICATIONS

Operational Modes: Constant Voltage with adjustable current limiting; Constant Current with adjustable voltage limiting; Automatic Crossover.

Mode Indicator: Front panel mode indicator light indicates when supply is operating in the constant current or current limiting mode.

Controls:
Voltage: Coarse and Fine; 0 to rated output; front panel.
Current: Coarse and Fine; 1% I_{rated} to rated output; front panel.
Input Power: Front panel switch and indicator.

Metering:
Voltage: Front panel voltmeter.
Current: Front panel ammeter.

Terminals:
Front Panel: Pos. Output (+V) — Neg. Output (−V) — Ground (G).
Rear Panel: Pos. Output (+V) — Neg. Output (−V) — Pos. Sensing (+S) — Neg. Sensing (−S) — Ground (G) — Remote Voltage Programming (RVP) — Remote Current Programming (RIP).

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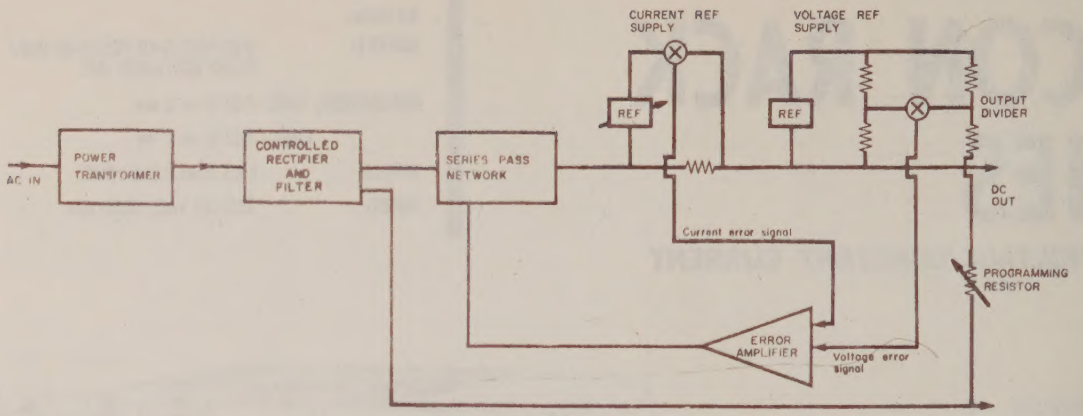


Block Diagram — Silicon Rack Series

DESCRIPTION

• The Trygon SILICON RACK SERIES units are designed for laboratory and systems applicatons. Their unique design provides operating flexibility and high reliability at high power output levels.

• CONSTANT VOLTAGE and CONSTANT CURRENT operation is provided with automatic crossover from one mode into the other. In the voltage mode, adjustable current limiting is provided while the current mode provides adjustable voltage limiting. A mode indicator light on the front panel indicates when the unit is operating in the constant current or current limiting mode. All units in this series have provisions for remote programming of voltage and current.

• MAXIMUM RELIABILITY is achieved through the use of proven design techniques, components selection, and rugged construction. High quality components are used throughout and power transistors are generously derated and temperature aged, zener diodes are temperature stabilized, electrolytic capacitors are computer grade with rated life in excess of 10 years, transformers meet or exceed the requirements of MIL-T-27A, and all Trygon power supplies are manufactured in accordance with the Quality Assurance requirements of MIL-Q-9858. The Silicon Rack Series units carry the Trygon 5 year warranty.

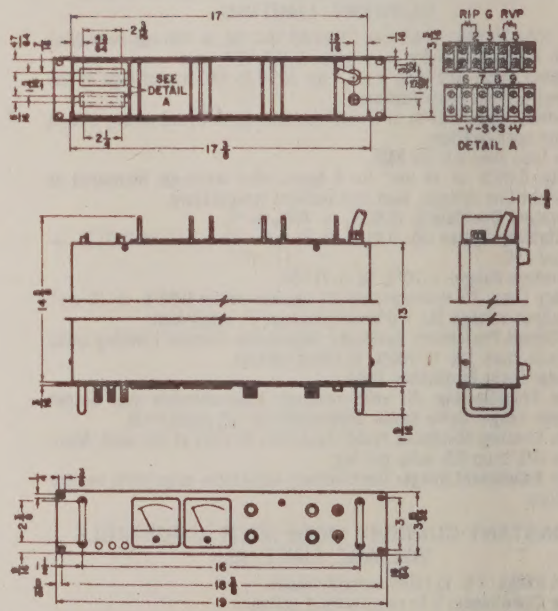
• AUTOMATIC TRACKING OVERVOLTAGE PROTECTION (OV)* is a patented automatic fail-safe overvoltage protection circuit pioneered by Trygon. The OV circuit protects the load against receiving a voltage in excess of the programmed output voltage of the supply. The protection point automatically tracks the programmed output voltage.

• SERIES OR PARALLEL OPERATION to increase voltage or current can easily be accomplished by connecting two or more supplies of this series together.

• SPECIAL MODIFICATIONS: The standard Silicon Rack RS Series units are available in five voltage ranges. Their outstanding versatility, reliability, and operating convenience make them ideally suited for a large majority of applications in standard form.

• TRYGON ELECTRONICS, INC., has available a number of standard options and modifications to extend even further the range of performance or application of each power supply. In addition, the Trygon Application Engineering department is available for consultation on specific applications.

*Optional



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SECTION 2
INSTALLATION AND OPERATION

2.1 MECHANICAL INSTALLATION

Rack Mounting

Any standard EIA relay rack will accommodate the Trygon Silicon Rack Series power supplies in only 3 1/2 inches of vertical mounting space. Mounting of the unit is easily accomplished by inserting four mounting screws through the slotted holes provided in the four corners of the front panel of the power supply, and on into the matching threaded holes of the relay rack.

Bench Use

Though designed primarily for rack mounting, the Silicon Rack Series power supply may be operated in a bench type configuration as well. It is therefore fully enclosed in a protective metal case, and equipped with rubber mounting feet which serve to protect the unit and the surface upon which it rests from scratching, and to provide an airflow channel under the unit for ventilation purposes.

2.2 ELECTRICAL CONNECTIONS

AC Input

A three terminal barrier strip mounted on the rear panel provides AC input connections to the unit.

The power handling ability of the AC power lines feeding AC power to the unit must be considered, as serious losses in regulation and substantial increases in ripple can occur as a result of insufficient power handling capacity of these lines. The AC impedance from the breaker box to the power supply input connector should not exceed 0.75 ohms. Any movable electric contact surface (such as the wiper arm of a variable transformer) should be kept clear of impedance producing oxide coatings.

Care should be exercised in selecting the proper wire size for the AC input lines. The figures listed in Table 2-1 will serve as a guide in making this selection.

TABLE 2-1 - AC INPUT WIRE SIZE

Length of Run (Single Lead)	Wire Size (AWG Standards)
10 feet or less	14
10 feet to 20 feet	12
20 feet to 50 feet	10
50 feet to 100 feet	8

Rear Panel Barrier Strip

A seven terminal barrier strip mounted on the rear panel provides programming and ground connections. Terminals 1 and 2 provide Remote Current Programming connections, terminals 4 and 5 provide Remote Voltage Programming connections, and terminal 3 is utilized as a ground connection.

DC Output

A heavy duty block containing stud type terminals is provided for DC output and sensing connections. Table 2-2 SHORTING LINK APPLICATION, lists the various shorting link connections required for any of the various modes of operation. Three (3) binding post terminals mounted on the front panel provide output and ground connections. These terminals are primarily for convenience purposes and for easy monitoring of the output.

Local Sensing

Local sensing of the output voltage is made at the rear panel output terminals. The shorting links must be placed across rear panel terminals (-V and -S) and (+V and +S).

Remote Sensing

Remote sensing of the output voltage is available only if the load is connected to the rear panel output terminals. The shorting links between the (-V and -S) and (+V and +S) terminals must be removed and separate sensing leads installed between the sensing terminals (-S and +S) and the load.

Local Programming

Local programming of either current or voltage is available by shorting the appropriate rear panel terminals. For local current programming operation, a shorting link should be placed across barrier strip terminals 4 and 5 (RVP). In both local current programming and local voltage programming operation, the output amplitude is dependent upon the setting of the appropriate front panel adjustment control.

Remote Programming

Remote programming of both voltage and current may be achieved by removing the shorting link from the appropriate barrier strip terminals and substituting a remotely operated adjustment control resistance in its place.

In the remote voltage programming mode of operation, the scale factor required for the remotely operated voltage adjustment control is 100 ohms per volt. In order for this remotely operated adjustment control to function properly, the front panel voltage adjustment controls must be set fully CCW. Operation of this power supply without either shorting link or remotely operated adjustment control connected across remote voltage programming barrier strip terminals 4 and 5 (RVP), will result in an unregulated output voltage.

The required size of the remote current programming resistor may be determined by use of the formula $R_{pgm} = 100 \left(1 - \frac{\text{Load Current}}{\text{Rated Current}}\right)$, where R_{pgm} is the remote program resistor, load current refers to the desired output current, and rated current refers to the maximum output current of the unit. To obtain proper operation of the remotely controlled current adjust control, it is necessary that the front panel current adjustment controls be set fully CW. Operation of this power supply without either shorting link or remotely adjusted current programming control connected across remote current programming barrier strip terminals 1 and 2 (RIP) will result in a complete loss of output current.

Shorting Links

The unit is shipped with shorting links in place across terminals 1 and 2, 4 and 5, -V and -S and +V and +S of the barrier strips. In this configuration, local programming and sensing is available at the barrier strip terminals. Table 2-2 lists the various shorting link connections and their functions.

TABLE 2-2 - SHORTING LINK APPLICATION

Terminals	Condition	Function
-V and -S +V and +S	Shorted Shorted	Local sensing and regulation at rear panel output terminals.
-V and -S +V and +S	Not Connected Not Connected	Remote sensing and regulation at load.
4 and 5	Shorted	Voltage programmed locally, output dependent upon voltage adjust pots.
4 and 5	Ext. PGM res.	Voltage programmed remotely, output dependent upon size of PGM resistor.
1 and 2	Shorted	Current programmed locally, output dependent upon current adjust pots.
1 and 2	Ext. PGM res.	Current programmed remotely, output dependent upon size of PGM resistor.

2.3 CONTROLS

Front Panel

TABLE 2-3 - FRONT PANEL CONTROLS

Name	Function
AC POWER	Power switch, controls input power.
VOLTAGE ADJUST (Coarse)	Potentiometer, adjusts voltage output.
VOLTAGE ADJUST (Vernier)	Potentiometer, adjusts voltage output.
CURRENT ADJUST (Coarse)	Potentiometer, adjusts current.
CURRENT ADJUST (Vernier)	Potentiometer, adjusts current.

Internal

All internal control settings have been factory preset, and require no additional adjusting. However, if it should become necessary to adjust any of the internal controls due to circuit changes caused by component aging or replacement, refer to the calibration section of this instruction manual.

2.4 OPERATION

Control Settings

Set all front panel controls fully CW so that unit will operate in the Voltage rather than Current Limiting mode.

Shorting Links

If Local Sensing rather than Remote Sensing operation is desired, ascertain that shorting links are in place across the appropriate terminals.

Grounding

Either side of the Output may be grounded, or the Output may be used in a floating condition.

Power On

Connect the power supply to a nominal AC power source. Set the Power switch to AC-ON, and observe that pilot lamp DS1 glows.

Warm-Up

No warm-up time is necessary to place the unit into operation. However, a 30 minute warm-up period is recommended to reach rated stability.

Series Operation

To operate two or more power supplies in a series configuration, connect the output of each power supply in series. When operating in this mode, it is necessary to adjust the output of each unit independently. The output voltage is equal to the sum of the voltage settings of each power supply.

Parallel Operation

A) With rated resistive load connected across the output of power supply A as shown in Figure 2-2A, set VOLTAGE ADJUST control to desired output voltage, and set CURRENT ADJUST control for maximum rated output current.

B) Connect power supply B as shown in Figure 2-2B. With no load across the output, set VOLTAGE ADJUST control for an output voltage 2 volts higher than the output voltage of power supply A. Place a short across the output terminals, and set the CURRENT ADJUST control for 1/2 the total load current requirement.

C) Remove all former output loads and connect the outputs of power supplies A and B in parallel with each other, and in parallel with the load, as shown in Figure 2-3.

D) If parallel operation of these two power supplies is desired for a systems application, it is important that both units be turned on simultaneously. It is therefore recommended that both power supplies be connected to a single large circuit breaker. Maximum output current will be twice that of either of the two power supplies, while minimum output current will be that of power supply B, or half the total load current.

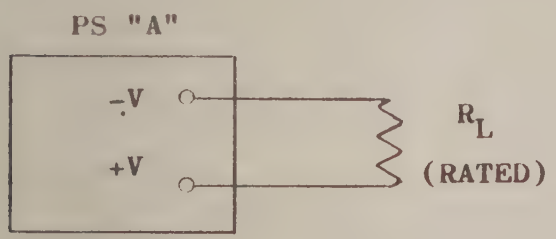


FIGURE 2-1A

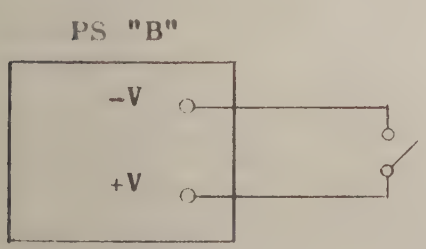


FIGURE 2-1B

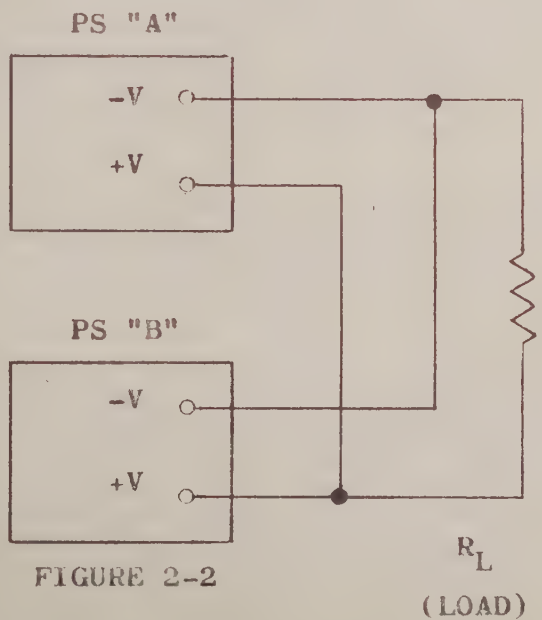


FIGURE 2-2

NOTE: Disconnect the gate lead from the OV SCR in power supply A.

SECTION 3
THEORY OF OPERATION

3.1 GENERAL

The purpose of the Silicon Rack Series power supplies is to transform and rectify the AC input into a well-regulated, stable and adjustable DC output. The following paragraphs describe the major circuits used in the power supplies. As each circuit is described, reference should be made to both the Block Diagram, Figure 3-1 and the Schematic Diagram in the rear of this manual.

Primary Input

Input power is obtained through power transformers T1 and T2 and full wave silicon diode rectifiers. Each pair of rectifiers provide the necessary DC voltages to the various sections of the unit.

When AC power switch S1 is set to AC-ON, AC pilot lamp DS1 glows, and AC power is applied to the power transformers. Regulated DC output power is immediately available from the power supply.

Reference Supply

The rectified and filtered voltage from rectifiers CR1 and CR2 and filter capacitor C1 is pre-regulated by Coarse Reference Regulator zener CR3. This provides a stabilized DC voltage to Constant Current Source Q2, whose output is regulated by Precision Voltage Reference zener CR16. Constant Current Source Q1 controls the drive to Q2 and in turn is controlled by Q2. The voltages developed across Constant Current Source References CR4 and CR16 are highly stable reference voltages established at a higher positive potential than the positive output of the supply.

Pre-Regulator

The purpose of the Pre-Regulator section is to maintain the unregulated input voltage on Input Filter Capacitor C22 at a suitable value compared to the output voltage in order to lower the power dissipation across the Series Pass section of the Series Regulator.

The method used to accomplish this is to "fire" a pair of SCR's (silicon controlled rectifiers), CR27 and CR28, at controlled points along the input sine wave to increase or decrease the potential to which the input filter capacitor may charge. The SCR's are "fired" (allowed to pass current) by the application of a positive pulse at the junction of gating resistors R57 and R58 from amplifier Q11, which amplifies the triggering pulse from unijunction transistor Q13. The unijunction transistor triggers the SCR's when charged sufficiently by timing capacitor C3 to cause conduction. The SCR's are turned off with each alternate half cycle of the input sine wave. Adjustment of R42 is factory set to the optimum full load firing point of the SCR's.

Series Regulator

The pre-regulated DC voltage from the SCR's is directed through the Series Pass transistors. The conduction of these transistors is controlled by circuitry which causes them to act as variable resistors. Their overall resistance varies in accordance with the need of the power supply to increase or decrease its output voltage or current.

The Series Pass transistors are controlled by several driver stages which amplify signals from the error amplifier.

Comparator and Error Amplifier

The voltage sensing and comparison is accomplished by differential amplifier Q10. A sample of the output voltage on the base of Q10 is compared to the stable reference voltage on the base of comparator Q9. An unbalance caused by a change in voltage at either the negative sensing terminal or across voltage adjustment controls R55 and R56 will appear as a voltage change in the collector of Q10.

This difference voltage is amplified by error amplifier Q6, and is used to regulate the Series Pass transistors via the Series Pass drivers. Error amplifier Q6 has two diode inputs to its base which form an OR gate for error signals. CR7 supplies error signals from the comparator, and CR6 supplies an error signal in the event of a short circuit, or if the power supply is driven into the current limiting mode of operation.

When operating in the current limiting mode, differential amplifier Q3 and Q4 become balanced, causing diode CR6 to conduct, and in turn drives error amplifier Q6 toward cut-off. This signal also causes Q7 to conduct, thereby causing current mode indicator lamp DS2 to glow.

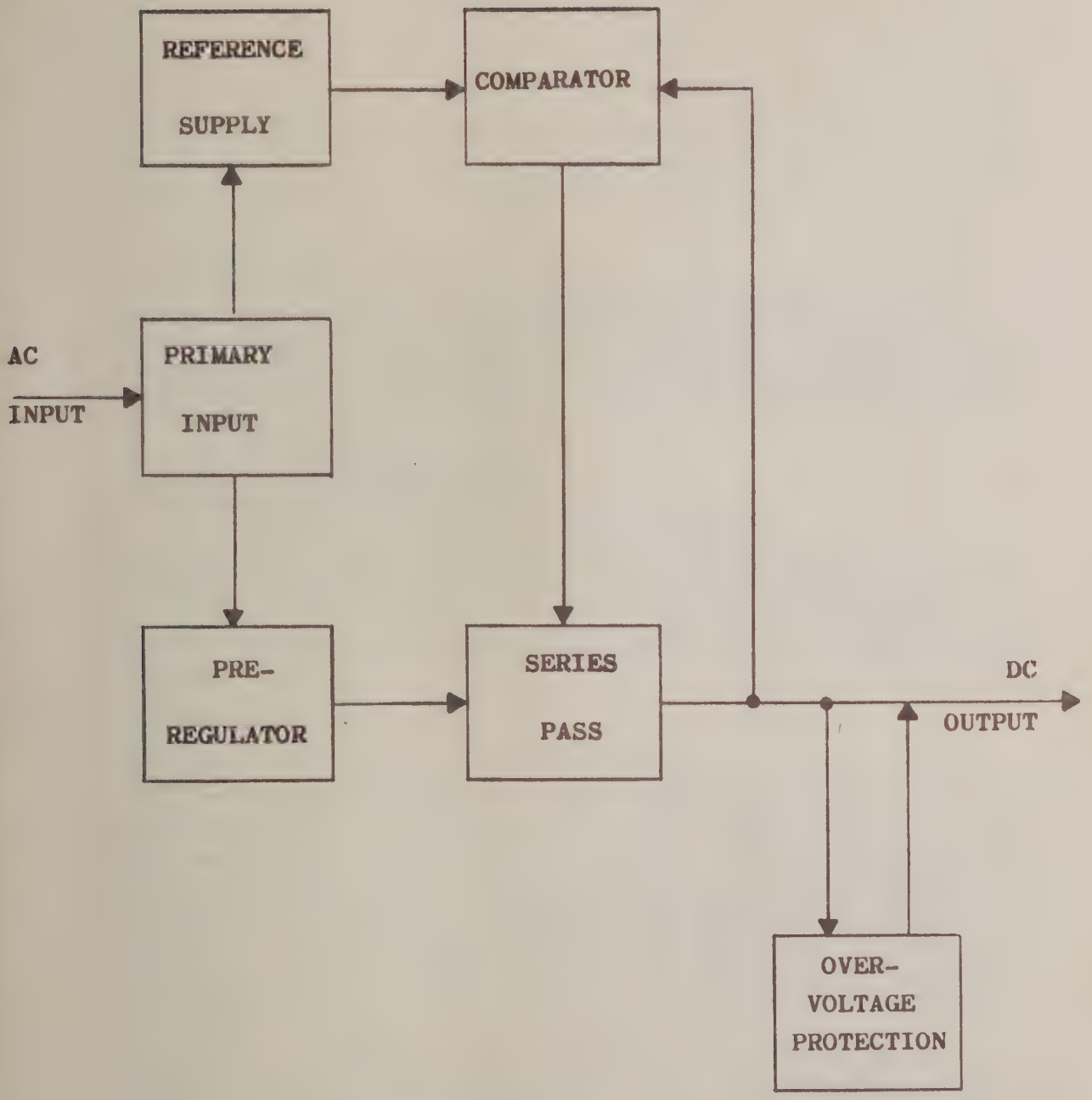


FIGURE 3-1 - BLOCK DIAGRAM

SECTION 4
MAINTENANCE

- W A R N I N G -
High Voltages Are Present
Use Caution

4.1 GENERAL

This power supply is a precision instrument. It is strongly recommended that only experienced trouble shooting personnel perform trouble shooting operations or attempt to repair the unit. If the power supply appears to be malfunctioning at all, the following procedure is recommended for isolating possible defects.

4.2 LOADS AND INTERCONNECTIONS

1) Disconnect all loads and interconnections.

2) Connect a resistive load across the output terminals, and operate the unit to determine whether the fault lies within the unit or externally. Observe that shorting links are in place across terminals 1 and 2, 4 and 5, -V and -S and +V and +S, and that all connections are tightly made.

4.3 TROUBLESHOOTING

1) Set the VOLTAGE ADJUST controls fully CW. Use a 20,000 ohms per volt voltmeter or oscilloscope to check the voltages across the various circuit components listed in the Troubleshooting Guide located in the rear of the manual. Any reading which is grossly incorrect indicates that the stage being tested or the one immediately preceding it, is defective. The Block Diagram, Schematic Diagram and appropriate sections of the Theory of Operation will prove helpful in any troubleshooting work. Proper polarity to be observed when testing can be easily obtained from the Schematic Diagram.

2) If voltage checks show no noticeable deviations from the prescribed values, disconnect AC power and proceed with point to point resistance checks across pots, switches, diodes, resistors, transistors, in that order.

3) When the trouble is of an intermittent nature such as poor regulation, ripple, etc., the use of an oscilloscope to determine dynamic changes will be necessary.

SECTION 5
CALIBRATION

5.1 GENERAL

The following adjustments should be made when necessary to assure optimum operating characteristics and maximum efficiency of the Trygon power supply.

5.2 TEST EQUIPMENT REQUIRED (or equivalent)

A) Oscilloscope, Tektronix Type 561
B) Differential Amplifier Plug In, Tektronix Type 63
C) Time Base Plug In, Tektronix Type 67
D) Differential VTVM, Fluke Model 825A
E) AC VTVM, Hewlett Packard Model 400D
F) VOM, Simpson Model 260
G) Variable Auto transformer, Powerstat Type 3PN136 (20 Ampere rating)

Shorting Link Application

For test purposes, shorting links should be connected across terminals 1 and 2, 4 and 5, -V and -S and +V and +S, to provide local sensing and local programming. To reduce pick up, shielded wire must be used for all connections between test equipment and the power supply being tested. To prevent ground loops, it is important that only one ground connection be made, as shown in Figure 5-1 and Figure 5-2. Tighten all terminal connections as securely as possible, and set all front panel controls fully CW.

5.3 CALIBRATION PROCEDURE

Pre-Regulator

A) With power supply operating without a resistive load across the output terminals, vary the VOLTAGE ADJUST controls until 100% of rated voltage output is indicated on the DC voltmeter. Set the AC POWER switch to OFF, and connect a resistive load across the output terminals. Set the AC POWER switch back to ON, and adjust the resistive load for rated current setting on ammeter.

B) Set oscilloscope to DC triggering mode and connect scope input across the positive terminals of input capacitor C22 and output capacitor C14.

C) Adjust Pre-Regulator Input Balance control R53 for a balanced 120 Hz sawtooth shaped waveform.

D) Adjust Series Pass Voltage control R49 for approximately 10 VDC, measured between the positive terminals of input capacitor C22 and output capacitor C14.

E) Vary AC input voltage 10% above and below the nominal input level. Observe that the voltage measured between the positive terminals of the input and output capacitors, does not vary by more than 20%, at either input voltage extreme.

Voltage Adjust Control

A) Maximum Voltage

Set front panel VOLTAGE ADJUST and VOLTAGE VERNIER controls fully CW. Adjust Maximum Voltage control R24 to obtain an output voltage 0.5 VDC in excess of the maximum rated output voltage.

B) Minimum Voltage

Set front panel VOLTAGE ADJUST and VOLTAGE VERNIER controls fully CCW. Adjust Minimum Voltage control R27 to obtain a negative output voltage of 0.1 VDC.

C) Readjustment

Adjustment of either Maximum Voltage control R24 or Minimum Voltage control R27 will have an effect upon the other. Therefore, these controls should be readjusted if necessary, as outlined in above paragraphs (A) and (B), upon initial completion of this adjustment.

NOTE

If partial rotation of the VOLTAGE ADJUST controls produces no apparent change in indicated output voltage, further rotation of these controls should not be attempted. Rotation of these controls fully CCW with little or no output voltage regulation can result in damage to the controls, the load, or both. Set the AC POWER switch to OFF, and proceed with the troubleshooting outlined in Section 4 (MAINTENANCE) of this instruction manual.

Set front panel VOLTAGE ADJUST and VOLTAGE VERNIER controls fully CCW and observe that the voltage indicated on the unit and test voltmeters drops slightly below the zero setting of the meters. The output voltage should be approximately negative 200 mv. Reset voltage controls fully CW.

Current Adjust Controls

A) Maximum Current

Connect a test ammeter having a full scale current indicating capacity of 150% that of the rated current output across the output terminals of the power supply. (Set all front panel controls fully CCW.) Apply power to the unit under test and slowly rotate CURRENT VERNIER control fully CW. Observe that the maximum current obtainable is approximately 105% that of the maximum rated current output. If it is not possible to achieve 105% of the maximum rated current output, adjust Maximum Current control R72

until that value is attained. Set AC Power Switch to OFF.

Connect a suitable load resistance across the output terminal connections. The load resistance must be able to dissipate the rated power of the unit (P = IE) and must be of sufficient value to yield the rated output current when the rated voltage is applied. Set AC Power Switch to ON. Note the voltage indicated on the Differential VTVM. Disconnect the resistive load from the output and observe the voltage indicated on the Differential VTVM. The maximum change in output voltage should not exceed by more than 0.01% or 3mv (whichever is greater) that of the output voltage indicated with the load resistance applied across the output terminals.

If it is not possible to maintain the load regulation as stated in the preceding paragraph, readjust Maximum Current control R72 slightly and recheck the load regulation.

B) Minimum Current

Connect test ammeter, having a full-scale current indicating capacity of 100 ma, across output terminals in place of a load resistor. Set all front panel controls fully CCW and apply power to the unit under test. Slowly rotate VOLTAGE ADJUST control in a CW direction, until current meter indicates a current flow somewhere between 0-50ma. Adjust Minimum Current control R80 for a nominal current indication of 1% of the rated current. Set the POWER ON switch to OFF.

Constant Voltage Operation

A) Load Regulation

With the equipment connected as shown in Figure 5-1, connect a suitable load resistance across the Output terminal connections. The load resistance selected must be able to dissipate the rated power of the unit (P = IE) and must be of sufficient value to yield the rated output current when the rated voltage is applied. Note the voltage indicated on the Differential VTVM. Disconnect the resistive load from the output. The maximum change in output DC voltage indicated on the Differential VTVM should not exceed by more than 0.01% or 3mv (whichever is greater) that of the output voltage indicated with the load resistance applied across the output terminals.

B) Line Regulation

Place the resistive load across the output and note the voltage indicated on the Differential VTVM. (Vary the input line voltage ± 10 percent. The maximum change in output voltage should not exceed by more than 0.01% or 3mv (whichever is greater) that of the output voltage measured at either extreme of the AC input.

C) Ripple Voltage

In order to reduce pickup, shielded test leads should be used in making ripple measurements. With the resistive load connected across the output terminals, measure the AC ripple with the AC VTVM. Vary the AC input power 10% above and below the nominal AC input level. The maximum ripple amplitude should not exceed 0.5 mv RMS.

Constant Current Operation

A) Load Regulation

With the equipment turned off, disconnect the resistive load from the output terminals. Connect a small current sensing resistor in series with the resistive load and then connect the load back across the output terminals. Selection of the proper value for the current sensing resistor may be easily made using the formula $R_S = \frac{I}{I_R}$ where R_S = Value of Current Sensing Resistor and I_R = Rated Load Current. Connect the equipment as shown in Figure 5-2, and apply power to the power supply.

Vary the VOLTAGE ADJUST controls and resistive output load as necessary, to achieve rated current and voltage output. Decrease the load resistance until current meter reading exceeds full scale indication. Rotate CURRENT ADJUST control CCW to return the current meter reading to full scale. Observe that the output voltage has decreased from its previous full scale reading, and that increasing the VOLTAGE ADJUST controls has no effect upon the output voltage or current. This indicates that the unit is now operating in the Constant Current Mode.

Measure the voltage across the small sensing resistor. Compute and note the current flow through this resistor. Change the output load from the resistive load previously used, to a short. Again measure the voltage across the small sensing resistor and compute the value of the current flow through this resistor. The change in current should not exceed by more than 0.5% the rated current previously noted with a full resistive load across the output.

B) Line Regulation

Replace the resistive load across the output and measure the voltage drop across the small sensing resistor. Compute and note the current flow ($I = \frac{E}{R}$) through this resistor.

Vary the input line voltage ± 10 percent.
Note the maximum change in voltage across the sensing resistor and compute the maximum current flow. The maximum change in current should not exceed by more than 0.5% the rated current previously noted at either extreme of the AC input.

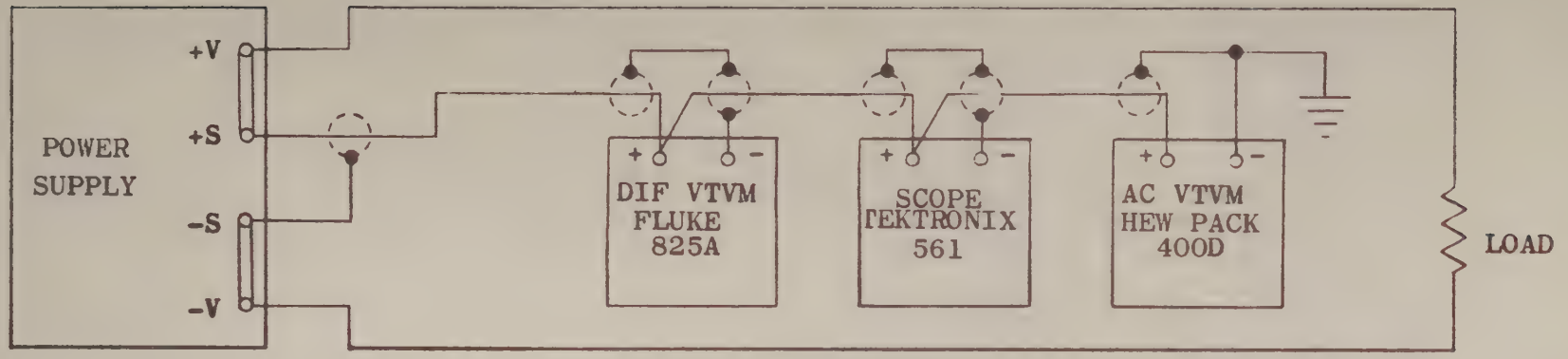


FIGURE 5-1
CONSTANT VOLTAGE OPERATION

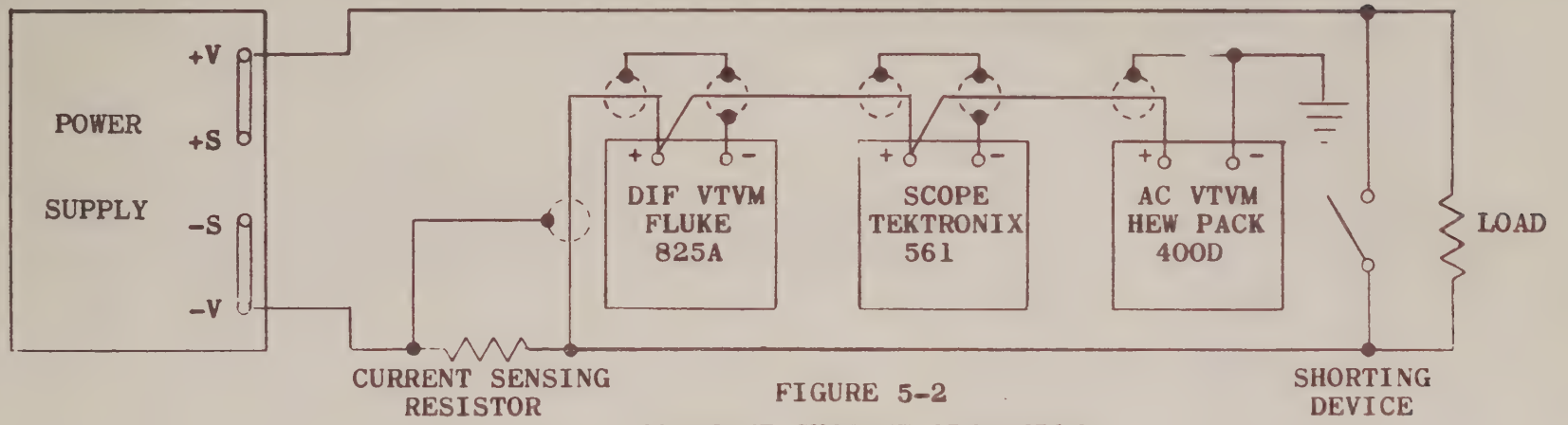


FIGURE 5-2
CONSTANT CURRENT OPERATION

C) Ripple Current

With the AC input line voltage adjusted to the nominal AC input voltage and the resistive load connected across the output, measure the amplitude of the AC ripple as seen across the sensing resistor with the AC VTVM. Compute and note the current flow. Vary the AC input line voltage ± 10 percent. Measure the maximum voltage drop and compute the maximum current flow. The maximum ripple current must not exceed by more than 0.25% or 5 ma (whichever is greater) that of the current flow noted during nominal input line voltage.

Semi-conductors commonly used in Trygon power supplies are available for replacement or spare parts use under the following Trygon, commercial manufacturer, or JEDEC part number.

SEMI-CONDUCTOR PART NUMBERS

TRYGON OR MFR P/N	JEDEC EQUIVALENT
TR346	2N1556
TR360	2N360
TR361	2N652
TR375	2N1533
TR496	2N497A
TR505	1N536
TR656	2N656
TR1132	2N1132
TR1490	2N1490
TR1493	2N1490
TR1494	2N1490
TR1495	2N3442
TR1512	2N2138
TR1590	2N3054
TR1592	2N3054
TR1593	2N3441
TR1690	2N3440
TR2060	2N2060
TR2195	2N656
TR2620A	1N2620A
TR2905	2N2905

Semi-conductors commonly used in Trygon power supplies are available for replacement or spare parts use under the following Trygon, commercial manufacturer, or JEDEC part number.

SEMI-CONDUCTOR PART NUMBERS

TRYGON OR MFR P/N	JEDEC EQUIVALENT
C35F	2N682
C50F	2N1910
E016	1N3938
E033	1N3940
G100B	1N4383
SC2	1N4383
SCR93-3	2N2575
SCR93-4	2N2576
SG1235	Replaced by G100B
SV515	1N821
UJ25	2N2647
16A507	2N2712
25H10	1N2129A
40108	1N1341

MANUFACTURER'S CODE LISTING - ELECTRICAL PARTS

1) The numbers designated in the SPARES column of the following ELECTRICAL PARTS LISTING indicate the recommended spare parts requirement for support of this equipment for a period of one year.
2) The code designations listed in the MFR column of the ELECTRICAL PARTS LISTING have been assigned to the following manufacturers:

CODE	MANUFACTURER	CODE	MANUFACTURER
A-B	ALLEN BRADLEY	LEE	LEECRAFT
ARN	ARNOLD JONES CINCH-JONES	MILW	MILWAUKEE
BUSS	BUSS	MOTO	MOTOROLA
CARL	CARLING	PHAO	PHAOSTRON
CD	CORNELL DUBILIER	RCA	RADIO CORPORATION OF AMERICA
CLAR	CLAROSTAT	ROT	ROTRON HOFF HOFFMAN
CORN	CORNISH	SAGE	SAGE KULKA KULKA
CTS	CHICAGO TELEPHONE SUPPLY	SANG	SANGAMO
ERIE	ERIE	SPRA	SPRAGUE HONEY HONEYWELL
GE	GENERAL ELECTRIC	STEV	STEVENS DELCO DELCO
GI	GENERAL INSTRUMENTS	TRAN	TRANSITRON
HOYT	HOYT	TRY	TRYGON
IREC	INTERNATIONAL RECTIFIER CORP.	UNI	UNITRODE
IRES	INTERNATIONAL RESISTOR CORP.	WILG	WILGREEN
OHM	OHMITE	WL	WARD LEONARD
SCHW	SCHWEBER	SEMC	SEMCOR
COMA	COMARK	MALL	MALLORY

LIST OF ELECTRICAL PARTS - RS320-1.5

Designation	Component	MFR	Part Number	Spares	
C1	Capacitor, 950 MFD, 50V	SANG	50001154-03	1	
C2	Capacitor, .047 MFD, 250V	COMA	MET MYLAR	1	
C4	Capacitor, .0033 MFD, 600V	ERIE	CK62AW332M	1	
C5,24	Capacitor, .001 MFD, 600V	ERIE	CK62BX102M	2	
C6	Capacitor, .01 MFD, 600V	ERIE	811Z5V103P	1	
C7,10	Capacitor, .1 MFD, 250V	COMA	MET MYLAR	2	
C8	Capacitor, 10 MFD, 50V	MALL	TTXE	1	
C9	Capacitor, 75 MFD, 15V	SPRA	40D756F015DD4	1	
C11,15-17,20, 30	Capacitor, .22 MFD, 400V	COMA	MET MYLAR	5	
C12,23	Capacitor, .47 MFD, 400V	COMA	MET MYLAR	2	
C13	Capacitor, 35 MFD, 25V	SPRA	40D356F025DD4	1	
C14	Capacitor, 750 MFD, 350V	GE	86F228S EE	1	
C19	Capacitor, 1 MFD, 400V	SPRA	148P	1	
C22	Capacitor, 2200 MFD, 400V	GE	86F2395-GH	1	
C27	Capacitor, 200 MFD, 25V			1	
C29	Capacitor, 90 MFD, 400V	GE	86F228S BA	1	
CR1,2,5,6,7,8, 9,10,11,12, 13,14,15,18, 19,20,23,24, 42,30,33,36,37,	Diode	GI	G100B	15	

LIST OF ELECTRICAL PARTS - RS320-1.5

Designation	Component	MFR	Part Number	Spares	
CR3	Diode	HOFF	IN1360A	1	
CR4,31	Diode, Zener	TRAN	IN751	2	
CR16	Diode, Zener	MOTO	IN2164A	1	
CR17	Diode, Zener	IREC	IN964B	1	
CR21,22,38,39, 40,41	Diode	GI	IN4385	5	
CR25,26,32	Diode	RCA	40114	3	
CR27,28	Rectifier-Silicon-Controlled	RCA	2N3670	2	
CR29	Diode	MOTO	IN968	1	
DS1	Pilot Light	FERI	5SRH-F2-R1-NISL	3	
DS2	Light Indicator	LEE	41N-G6-1317-9B5T	3	
F1	Fuse	BUSS	MDL10	5	
L1,2	Core	ARN	A9301572	2	
M1	Meter, 350V	HONEY	MS2T	1	
M2	Meter, 1.5A, Int. Shunt	HONEY	MS2T	1	
Q1,20	Transistor	GE	TR2195	2	
Q2,6,12,14	Transistor	TRAN	TR1132	4	
Q3,4,5,7,8,9, 10,21	Transistor	GE	16A507	7	

LIST OF ELECTRICAL PARTS - RS320-1.5

Designation	Component	MFR	Part Number	Spares	
Q11	Transistor	GE	TR497	1	
Q13	Unijunction, UJ25	GE	4JX5E600	1	
Q15,16,31	Transistor	DELCO	DTS 423	3	
Q18	Transistor	RCA	TR1592	1	
R1	Resistor, 100Ω, 10W	WL	10XM100	1	
R2	Resistor, 10KΩ, .5W, 2%	IRES	RL20	1	
R3	Resistor, 49.92KΩ, .5W, .5%	IRES	CECTO	1	
R4	Resistor, 1.18KΩ, .5W, 1%	IRES	CECTO	1	
R5	Resistor, 700Ω, 1W, 3%	SAGE	1000S700-3	1	
R6,7,10,20,21, 73,74	Resistor, 1.96KΩ, .5W, 1%	IRES	CECTO	5	
R8,28,51,53	Resistor, 100Ω, .5W, 10%	AB	RC20GF101K	3	
R9,23	Resistor, 750Ω, .5W, 1%	IRES	CECTO	2	
R11	Resistor, 470Ω, .5W, 10%	AB	RC20GF471K	1	
R12	Resistor, 4.7KΩ, .5W, 10%	AB	RC20GF472K	1	
R13,61,63,67	Resistor, 1KΩ, .5W, 10%	AB	RC20GF102K	4	
R14	Resistor, 10KΩ, .5W, 10%	AB	RC20GF103K	1	
R15	Resistor, 75KΩ, .5W, 1%	IRES	CECTO	1	
R16	Resistor, 560Ω, .5W, 10%	AB	RC20GF561K	1	
R17	Resistor, 402Ω, .5W, 1%	IRES	CECTO	1	
R18	Resistor, 1.5KΩ, 1W, 3%	SAGE	1000S1500-3	1	

LIST OF ELECTRICAL PARTS - RS320-1.5

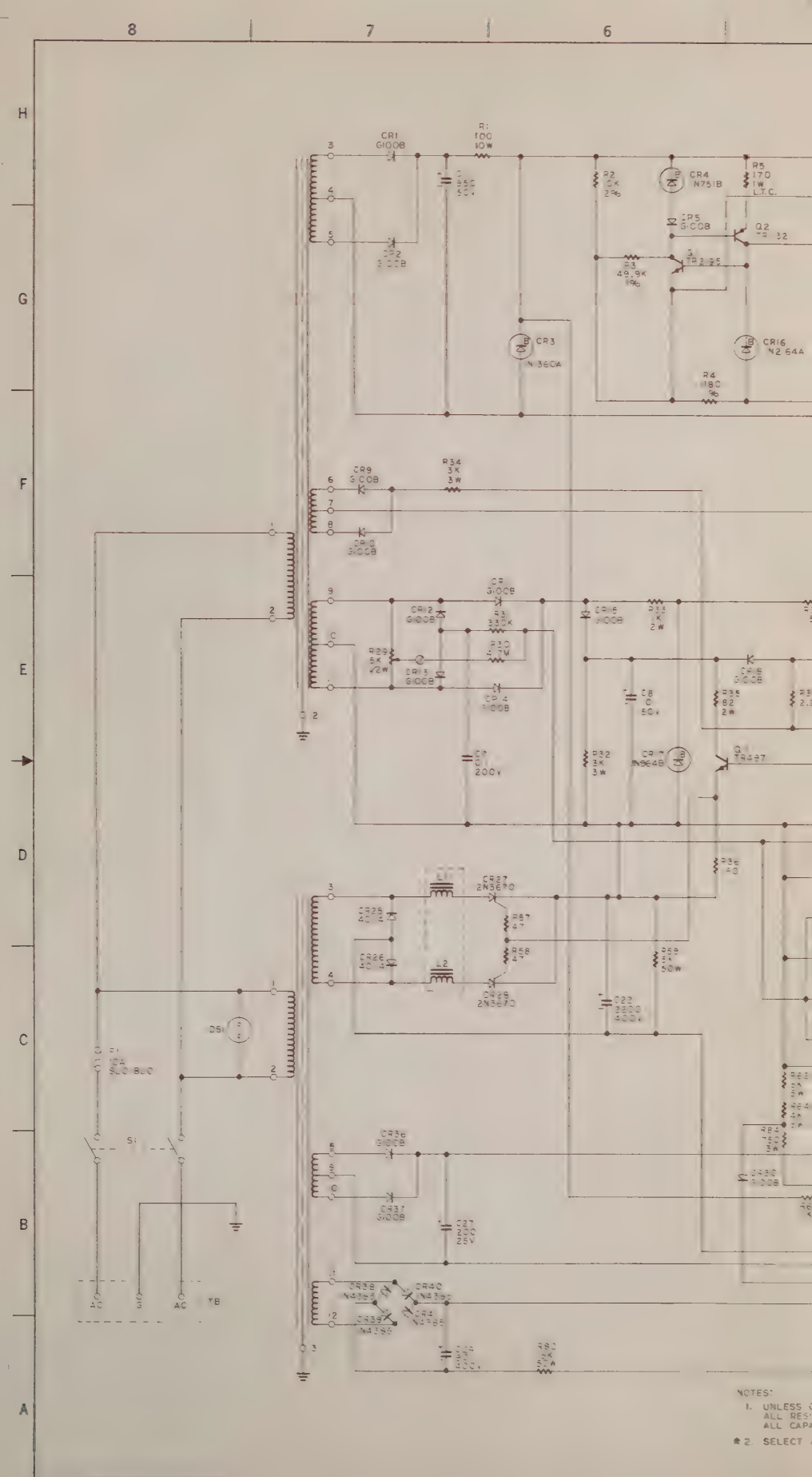
Designation	Component	MFR	Part Number	Spares	
R19	Resistor, 750Ω, 1W, 3%	SAGE	1000S750-3	1	
R22	Resistor, 800Ω, .5W, 1%	IRES	CECTO	1	
R24	Potentiometer, 250Ω, 1.5W, 20%	CTS	110	1	
R25	Resistor, 150Ω, 3W, 3%	SAGE	1300S150-3	1	
R26	Resistor, 250Ω, 3W, 3%	SAGE	1300S250-3	1	
R27,72	Potentiometer, 150Ω, 1.5W	CTS	110	2	
R29	Potentiometer, 5KΩ, 1.5W, 20%	CTS	110	1	
R30	Resistor, 4.7MΩ, .5W, 10%	AB	RC20GF475K	1	
R31	Resistor, 330KΩ, .5W, 10%	AB	RC20GF334K	1	
R32,34	Resistor, 3KΩ, 3W, 3%	SAGE	1300S3000-3	2	
R33	Resistor, 1KΩ, 2W, 10%	IRES	BWH	1	
R35	Resistor, 82Ω, 2W, 10%	IRES	BWH	1	
R36,37	Resistor, 150Ω, .5W, 10%	AB	RC20GF151K	2	
R38,68	Resistor, 2.2KΩ, .5W, 10%	AB	RC20GF222K	2	
R39	Resistor, 680Ω, .5W, 2%	IRES	RL20	1	
R40	Resistor, 2.95KΩ, .5W, .5%	IRES	CECTO	1	
R41	Resistor, 330Ω, .5W, 10%	AB	RC20GF331K	1	
R42,44	Potentiometer, 25KΩ, .25W, 10%	CTS	UPE200R	2	
R43,45,46	Resistor, 4.99KΩ, .5W, 1%	IRES	CECTO	3	
R47	Resistor, 1.5MΩ, .5W, 10%	AB	RC20GF155K	1	
R48,49	Resistor, 100KΩ, .5W, 1%	IRES	CECTO	2	
R50	Resistor, 30.1KΩ, .5W, 1%	IRES	CECTO	1	

LIST OF ELECTRICAL PARTS - RS320-1.5

Designation	Component	MFR	Part Number	Spares	
R52	Resistor, 30KΩ, 5W, 5%	WL	5XM30000	1	
R54	Resistor, 15KΩ, .5W, 10%	AB	RC20GF153K	1	
R55	Potentiometer, 250Ω, 2W, 10%	CLAR	B1648	1	
R56	Potentiometer, 50KΩ, 4W, 10%	CLAR	A7377	1	
R57,58	Resistor, 47Ω, .5W, 10%	AB	RC20GF470K	2	
R59,60	Resistor, 5KΩ, 50W, 5%	IRES	4D	2	
R62	Resistor, 5KΩ, 5W	WL	5XM5000	1	
R64	Resistor, 4KΩ, 5W, 5%	WL	5XM4000	1	
R65,66	Resistor, .7Ω, 3W, 3%	SAGE	1300S.7-3	2	
R70	Resistor, 100Ω, .5W, 1%	IRES	CECTO	1	
R71	Resistor, 301Ω, .5W, 1%	IRES	CECTO	1	
R75	Resistor, 604Ω, .5W, 1%	IRES	CECTO	1	
R76	Resistor, .67Ω, 25W	IRES	2D	1	
R77	Potentiometer, 100Ω, 2W, 10%	CLAR	B6132	1	
R78	Potentiometer, 10Ω, 2W, 10%	CLAR	B2816	1	
R79	Resistor, 340Ω, .5W, 1%	IRES	CECTO	1	
R80	Potentiometer, 2KΩ, 1.5W, 20%	CTS	110	1	
R82,83	Resistor, 15KΩ, 50W, 5%	IRES	4D	2	
R84	Resistor, 700Ω, 3W, 3%	SAGE	1300S700-3	1	
R89	Resistor, 750Ω, 3W, 3%	SAGE	1300S750-3	1	
S1	Switch DPST	CARL	NST52K	1	

LIST OF ELECTRICAL PARTS - RS320-1.5

Designation	Component	MFR	Part Number	Spares	
T1	Transformer	TRY	RT320-1.5-1	1	
T2	Transformer	TRY	RT320-1.5-2	1	
TB1	Strip Barrier	KULKA	670Y 3	1	
TB2	Strip Barrier	KULKA	670Y 7	1	
TB3	Output Block	TRY	B7646	1	
TB4	Strip Term	JONES	3 170	1	
TB5,6	Strip Barrier	KULKA	599C9	2	



NOTES:

1. UNLESS
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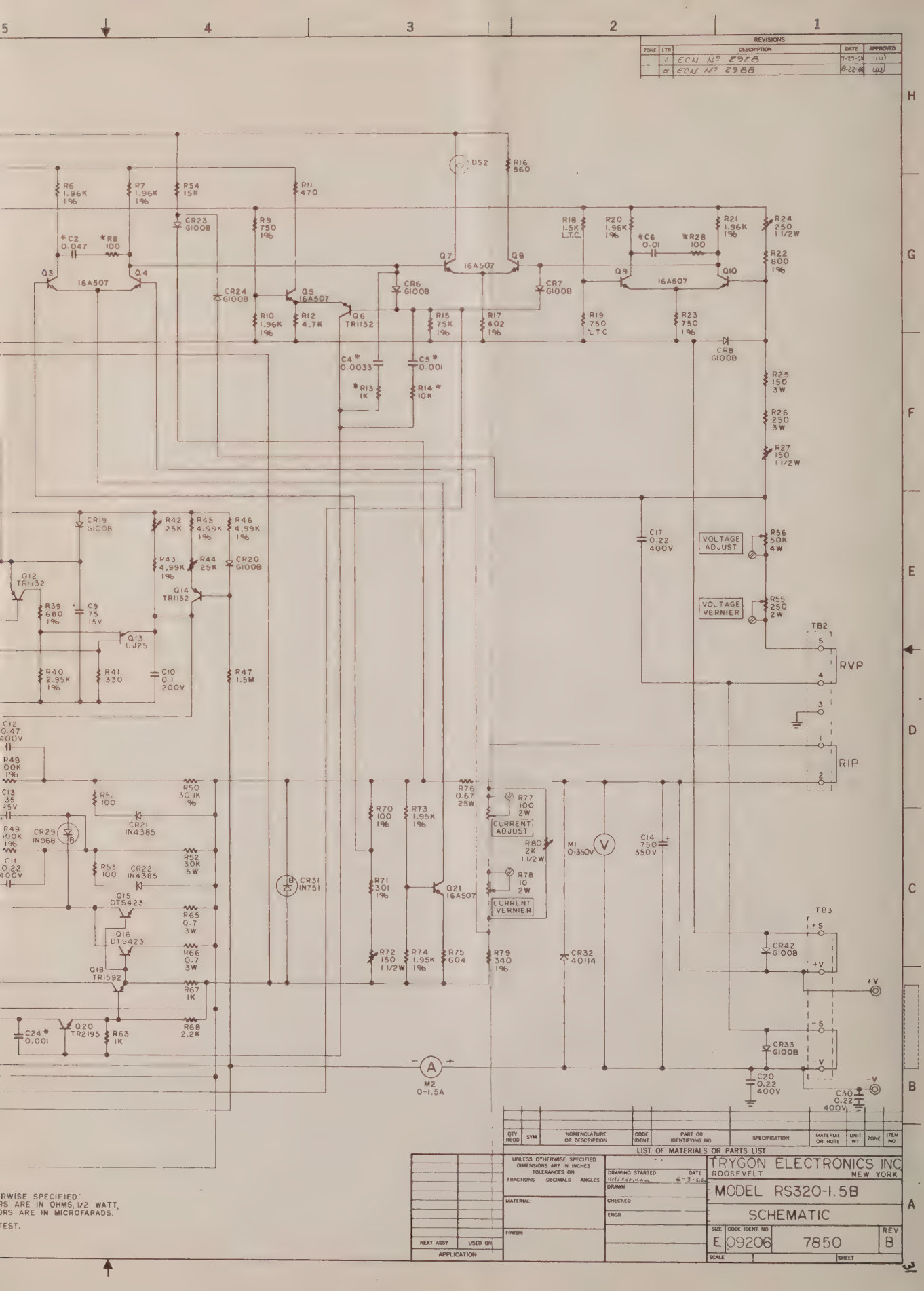
*2. SELECT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DS2
R16 560
R6 1.96K 1%
R7 1.96K 1%
R54 15K
R11 470
CR23 G100B
R9 750 1%
*C2 0.047
*R8 100
Q3
16A507
Q4
CR24 G100B
Q5 16A507
R10 1.96K 1%
R12 4.7K
Q6 TRI132
R15 75K 1%
R17 402 1%
Q7
16A507
Q8
CR6 G100B
CR7 G100B
R18 1.5K LTC
R20 1.96K 1%
*C6 0.01
*R28 100
R21 1.96K 1%
R24 250 1 1/2W
R22 800 1%
Q9
16A507
Q10
R19 750 LTC
R23 750 1%
CR8 G100B
C4* 0.0033
C5* 0.001
*R13 1K
R14* 10K
R25 150 3W
R26 250 3W
R27 150 1 1/2W
C17 0.22 400V
VOLTAGE ADJUST
R56 50K 4W
VOLTAGE VERNIER
R55 250 2W
TB2
5
4
3
2
RVP
RIP
CR19 G100B
R42 25K
R45 4.99K 1%
R46 4.99K 1%
R43 4.99K 1%
R44 25K
CR20 G100B
Q12 TRI132
Q14 TRI132
R39 680 1%
C9 75 15V
Q13 UJ25
R40 2.95K 1%
R41 330
C10 0.1 200V
R47 1.5M
C12 0.47 400V
R48 00K 1%
C13 35 25V
R5. 100
R50 30.1K 1%
CR21 IN4385
R49 00K 1%
CR29 IN968
C11 0.22 400V
R53 100
CR22 IN4385
R52 30K 5W
Q15 DTS423
Q16 DTS423
R65 0.7 3W
R66 0.7 3W
Q18 TRI592
R67 1K
C24* 0.001
Q20 TR2195
R63 1K
R68 2.2K
R70 100 1%
R73 1.95K 1%
R76 0.67 25W
R77 100 2W
CURRENT ADJUST
R80 2K 1 1/2W
R78 10 2W
CURRENT VERNIER
CR31 IN751
R71 301 1%
Q21 16A507
R72 150 1 1/2W
R74 1.95K 1%
R75 604
R79 340 1%
CR32 40114
M1 0-350V
V
C14 750 350V
TB3
+S
+V
-S
-V
CR42 G100B
CR33 G100B
C20 0.22 400V
C30 0.22 400V
M2 0-1.5A
A
RWISE SPECIFIED:
RS ARE IN OHMS, 1/2 WATT,
ORS ARE IN MICROFARADS.
TEST.
QTY REQD SYM NOMENCLATURE OR DESCRIPTION CODE IDENT PART OR IDENTIFYING NO. SPECIFICATION MATERIAL OR NOTE UNIT WT ZONE ITEM NO
LIST OF MATERIALS OR PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES
DRAWING STARTED DATE 6-3-66
DRAWN
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ENGR
MATERIAL:
FINISH:
NEXT ASSY USED ON
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TRYGON ELECTRONICS INC
ROOSEVELT NEW YORK
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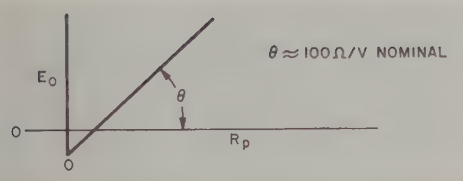
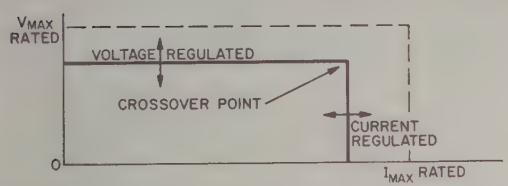
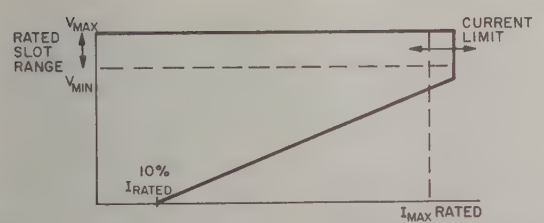
SCHEMATIC
SIZE E CODE IDENT NO. 09206 7850 REV B
SCALE SHEET







power supply handbook of applications . . .

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APPLICATION NOTES

These application notes have been prepared to aid the engineer in selecting a power supply to meet exacting specifications for laboratory and system requirements. On the following pages are described useful power supply applications as well as standard options, modifications and protective circuits relative to Trygon power supplies.

1. REMOTE VOLTAGE PROGRAMMING WITH RESISTANCE

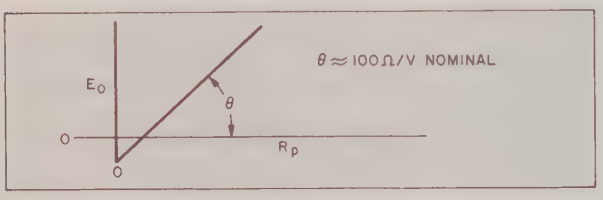
The remote voltage programming feature incorporated in almost every Trygon power supply enables the output voltage to be controlled in proportion to an external resistance located between the programming terminals.

Most Trygon power supplies use a 100 ohms/volt ratio for programming. There are some supplies, however, with different ratios. The particular ratio is always specified on the applicable data sheet. Current through the programming resistor will always correspond to the inverse of the programming ratio, i.e., 100 ohms/volt = 10 milliampere, 50 ohms/volt = 20 milliamperes.

The programming resistor used should have a temperature coefficient of 20 ppm/°C or less and a conservative wattage rating to avoid changes of the resistance value due to heating.

When the leads to the programming resistor traverse electric fields, care should be taken to avoid pickup of ripple. It is recommended that a shielded two wire cable be used with one end of the shield connected to the ground terminal of the power supply and the other end unconnected.

If the programming leads are of sufficient length to add appreciable resistance at the remote terminus, the power supply may be incapable of being programmed to zero output with a short circuit across the terminus. Trygon overcomes this problem by providing a zero offset (negative voltage) with the programming terminals of the power supply shorted. The remote programming characteristic is shown below for 100 ohms/volt units.

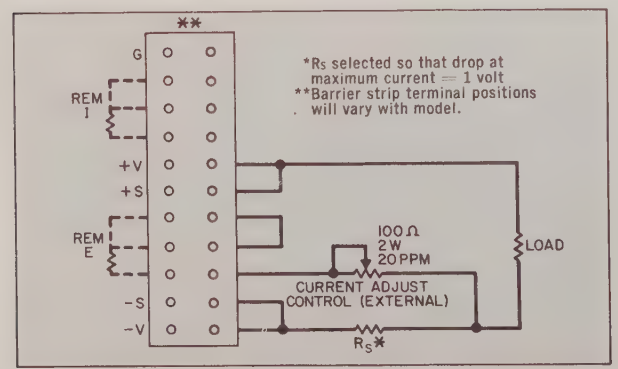


The angle θ or ohms/volt ratio is normally subject to small variances from nominal value, by 1% to 7%. Programming linearity will, however, be better than 1%. On many models, Trygon can specially align the remote programming factors to reduce the zero offset or slope variation for specific applications. Please consult the factory for details.

2. IMPROVED CONSTANT CURRENT REGULATION

It is possible to improve the current regulation of a multi-purpose power supply with automatic voltage-current crossover characteristics, by using an external current sensing resistor. With this technique, the current regulation of Trygon power supplies can be improved to better than 0.05% or 1 ma.

The diagram below shows the actual terminal connections, on the barrier strip of a typical Trygon power supply, to achieve improved constant current regulation using the external current sensing resistor technique.



In this configuration, the current regulation will be equal to the inherent voltage regulation of the supply plus the variation caused by changes in the resistance of the current sensing resistor. The current sensing resistor must handle the full rated current and the drop across it will subtract from the maximum available voltage. Therefore, the maximum recommended drop is of the order of 1 volt.

3. PARALLEL OPERATION OF POWER SUPPLIES

Two power supplies may be connected in parallel when a greater current, than that obtainable from a single power supply, is required. Paralleling of two power supplies is not recommended unless they contain automatic or foldback current limiting. Current limiting prevents damage to the supply by large circulating currents resulting from any difference in voltage. Most Trygon power supplies contain current limiting with automatic crossover capabilities for such parallel operation.

The supplies that are to be connected in parallel need not have equal ratings nor be from identical series. One of the two supplies should be set to a slightly higher output voltage than that required, and their respective plus and minus terminals connected together.

To achieve remote sensing, in parallel-connected supplies, connect the sensing leads of the lower voltage supply to the load.

The following are some precautions which must be noted in parallel operation:

a. The inherent load regulation of the parallel-connected supplies is equal to the nominal regulation of the individual supply plus the difference between the nominal voltage setting of the two supplies.

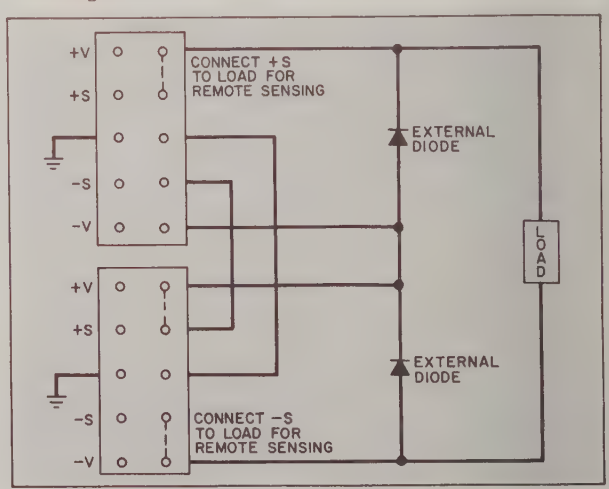
b. When parallel-connected supplies are used in a systems application, it is advisable to turn on both units simultaneously. The inputs of both supplies should be connected to a single circuit breaker.

c. When two supplies are operating in parallel it is not advisable to set either voltage control near zero since this would cause severe damage to the control.

4. SERIES OPERATION OF POWER SUPPLIES

Two or more power supplies (of the current limiting or constant current type) may be operated in series to obtain higher voltages than normally available from a single supply.

Interconnections required to achieve series operation are shown in the diagram below.



Each supply should have its +S, +V, —S and —V terminals jumpered as shown. These terminals should be removed from ground. A diode, capable of handling the short circuit current, is connected anode to minus and cathode to plus across each supply. These diodes provide a low impedance path when the load is shorted. (Most Trygon power supplies contain this diode as part of their standard circuitry).

When two supplies are series-connected it is not advisable to operate at voltages greater than 500 volts, thereby avoiding the possibility of capacitor and transformer breakdown. Normal current regulation and limiting may be achieved by setting the current adjustment control on each supply to the desired value.

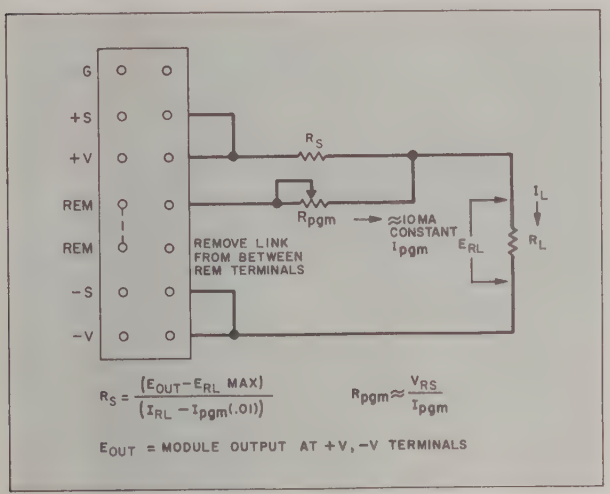
To prevent ripple and circulating ground currents, it is advisable to connect the chassis ground terminals together.

Note that the sensing terminals on the common terminals are connected together and only one of the common voltage terminals is connected to its sensing terminal. This is done to insure that the rated voltage regulation is maintained at the load when using remote sensing.

5. REMOTE CURRENT PROGRAMMING — MODULAR SUPPLIES

Due to the compactness of design, adjustable current limiting and current programming cannot be built into the modular series power supplies. However, with the addition of an external current sensing resistor, the remote voltage programming capability of the module can be used for current programming.

The circuit required to achieve current programming is shown below.



From the diagram it can be seen that with a constant load, I_L is directly proportional to R_{pgm}.

For optimum operation, R_S should be chosen so that V_S is approximately 2 volts, hence the maximum voltage available at the load is $V_{rated} - 2$.

6. REMOTE CURRENT PROGRAMMING — SERIES RS, SHR, M

Most Trygon power supplies that have adjustable current limiting are also capable of remote current programming. The range of current programming is from approximately 1% of the rated current to the full rated output.

The programming factor is an inverse ratio, i.e., the higher the resistance the lower the current output. This programming factor is approximately equal to $100\left(\frac{1-I_{load}}{I_{rated}}\right)$.

It is evident, therefore, that for a load current equal to the rated current, the programming resistor would be zero ohms (short circuit) and for minimum current limiting, approximately 100 ohms. A 125 ohm 2 watt low temperature coefficient variable resistor is recommended for full range programming.

7. DC WIRE LOSS CONSIDERATIONS

The result of wire losses of the load lines is best shown by an example: Consider a Trygon Model HR20-5B Medium Power Half Rack, rated at 20 volts at 5 amps. Load regulation is specified as 0.01% or 2 mv. If the load wire is connected to the supply by three feet of AWG #12 wire (a total of six wire-feet), the voltage drop in the leads would be approximately 60 mv at 4 amps.

The Cable Voltage Drop Table is provided so that the line voltage drop can be readily determined. This table is conservative and is based on a cable temperature of 60°C which takes into account self-heating of cable copper. Note that the table gives voltage drop in ampere-feet.

CABLE VOLTAGE DROP TABLE

	WIRE SIZE						
	#2	#4	#6	#8	#10	#12	#14
Ampere Feet	**Voltage Drop (Volts)**						
2000	0.8						
1000	0.4	0.6					
900	0.4	0.6					
800	0.3	0.5	0.8				
700	0.3	0.4	0.7				
600	0.2	0.3	0.6				
500	0.2	0.3	0.5	0.8			
400	0.2	0.2	0.4	0.6			
300	0.1	0.2	0.3	0.5	0.7		
200	0.1	0.1	0.2	0.3	0.6	0.8	
100	.05	.05	0.1	0.2	0.2	0.4	0.6

Ampere Feet = Load Current in Amperes times the distance in Feet from Power Supply to Load.

8. REMOTE SENSING

Remote sensing circuits enable the specified regulation to be maintained at the load by permitting the regulator circuits to sense the output voltage at the load. Trygon power supplies, with remote sensing, will compensate a voltage drop of about 0.5 volts in each leg, automatically. If voltage drops greater than this are anticipated, contact the Trygon Applications Engineering Department.

The following precautions and suggestions apply to remote sensing lead connections for Trygon Power Supplies:

a. The use of a twisted shielded pair is recommended to minimize inductive pickup.

b. Number 18 AWG wire may be used. Sensing lead current is about 100ma per leg.

c. Ground the sensing lead shield at the power supply end only to minimize noise pickup.

d. Load current must not be allowed to flow in sensing leads since it will damage the supply. Therefore, when switching leads with the power supply energized always connect the load lead first and then the sensing leads.

e. To avoid pickup of spurious signals and RF noise by the sensing leads, check the output of the supply with a scope to determine the presence of high frequency spurious signals. To eliminate these spurious signals, if they exist, bypass the RF to ground by connecting a capacitor to ground from the remote sensing terminals and/or across the sense terminals. Use the minimum possible value of capacitance since high values will increase the recovery time of the supply.

f. In any power supply system using remote sensing, load on-off switching will result in an overvoltage condition when voltage drops are present in the load leads. Rated voltage at the load is maintained by charging the power supply output capacitor to $E_{co} = E_o + IR_{load}$. E_o is the load voltage and IR_{load} are the voltage drops. When the load is switched off, E_{co} appears at the load end of the output leads. It is higher than the programmed voltage by an amount equal to the voltage drop. The duration of the overvoltage condition depends on the output capacitance and the bleeder resistance of the supply. The overvoltage can be reduced by a capacitor at the load. This capacitor, however, forms an RC circuit with the lead resistance, the time constant of which increases the duration of the overvoltage transient and also lengthens the response time of the supply.

g. On most supplies (modules excluded) diodes protect the power supply against damage resulting from open circuit sensing leads. If the load line were to open while the sensing leads remain connected to the load, the voltage will rise by an amount equal to the difference between the diode saturation voltages and the voltage drop in the load leads.

If these precautions and suggestions are observed, the remotely sensed load voltage will meet specifications for line regulation, static load regulation, temperature coefficient and stability.

9. STANDARD FEATURES, OPTIONS AND MODIFICATIONS

Trygon manufactures, at present, over two hundred models of standard transistorized power supplies. In the great majority of applications, an exact fit to requirements may usually be found. On occasion, however, a requirement exists which can be met only by modifying a standard unit or fitting to it one or more of the standard options available. "Standard" options or modifications are those called for frequently enough that design and manufacturing methods have been worked out to permit ready inclusion of them in a standard unit.

A. Electrical Options and Modifications

1. Automatic Tracking Overvoltage Protection (OV) (Option)
   Trygon's unique, fully automatic, fail/safe, circuitry for protection of the load against voltages in excess of programmed voltage.
2. High Stability (X) (Option)
   Stability of 0.01% or 2 mv with a temperature coefficient of (0.01% + 100μv)/°C.
3. Super High Stability (XX) (Modification)
   Certain models can be furnished with a stability of 0.005% or 1 mv with a temperature coefficient of (0.005% + 50μv)/°C. For fixed voltage outputs the stability and time constant can be reduced to 0.002%. Consult the factory for details.
4. External Voltage Programming (Modification)
   Circuit modification permitting programming of output current or voltage by means of an external voltage source.
5. Tracking (Modification)
   Modification permitting interconnection of two or more power supplies so that the positive outputs and negative outputs maintain a fixed relationship once established, regardless of voltage change in either supply.
6. Slaving (Modification)
   Permits interconnection of two or more power supplies of the same output polarity so that the output level of all supplies is controlled by the "Master" unit.
7. Mid-Voltage Protection (Modification)
   Permits interconnection between supplies of a multiple supply system such that all supplies shut off when any of the other supplies lose output voltage.
8. Over and Undervoltage Protection (Modification)
   A protection system that shuts off the supply when the output voltage exceeds or drops below the set output voltage.
9. Multiple Outputs (Modification)
   Permits the supply to furnish additional DC outputs with the same or differing regulation, ripple, etc., or AC outputs, e.g., for filament power, etc.

B. Mechanical Options and Modifications

1. Meters or Elimination of Meters (Option and Modification)
   All rack-type supplies may be furnished with or without meters. MIL-M-10304B meters may be substituted, if required.
2. Chassis Slides (Modification)
   Provisions for chassis slides or mounting of chassis slides can be accomplished on all Trygon Power Supplies.
3. Special Connectors (Modification)
   Special connectors may be mounted on the rear panel for AC input and DC output connection, as required.
4. Special Handles (Modification)
   Special handles may be placed on the front panel of any Trygon Power Supply that is normally furnished with handles.
5. Special Front Panel (Modification)
   Special front panels may be furnished, including special paint, panel fasteners and oversize panels for RFI gasketing.
6. Rack Adapters (Option)
   Rack adapters are available for all Trygon power supplies that are not packaged in a 19" wide panel.

10. PROTECTION CIRCUITS

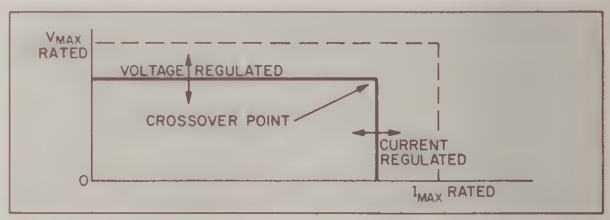
Dependable safeguards, properly used, can guarantee dependable service and long life for any power supply. Trygon has, through years of experience, provided many safeguards and protective circuits in its power supplies which have been proven through many thousands of hours of continuous and dependable use.

A. Automatic Tracking Overvoltage Protection
   One of these safeguards is a patented, fail/safe automatic tracking overvoltage protection circuit, pioneered by Trygon. This circuit protects the power supply load from receiving a voltage that is in excess of the programmed output voltage of the power supply, either internally or externally caused. This optional overvoltage circuit is fully automatic and does not require a separate voltage setting.

B. Short Circuit and Overload Protection
   All Trygon power supplies are provided with complete and automatic protection against short circuits and overloads. Five different methods are used, depending on the circuit requirements and application of each model.

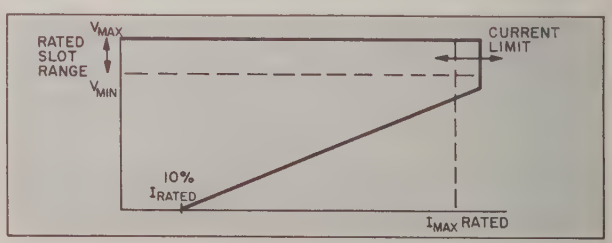
1. Automatic Adjustable Current Limiting (ACL) automatically and continuously compares the load current with a reference previously established by adjustment. In the event of a short circuit or overload condition, the output current is limited to the preselected value. When the short or overload condition is removed, the supply automatically returns to normal operation as a constant voltage supply.

   This method of current limiting permits the power supply to be operated as either a constant voltage or constant current supply. Since the power supply is provided with independent sensing circuits for current and voltage, the crossover point or transition between constant voltage and constant current is very sharp as shown in the illustration. In addition, mode indicator lights are provided on many units to indicate that the supply is in the current limiting mode.



   Most Trygon power supplies of this type are also fully specified for regulation, ripple and other characteristics in this constant current mode.

2. Current Limiting (CL) is similar to automatic adjustable current limiting except that the crossover point is not as sharply defined. When precise constant current operation is not an application criteria, current limiting suffices to protect both the load and the supply from excessive currents. This type of protection is normally preset to rated maximum load current.
3. Automatic Electronic Switching (AES) short circuit protection automatically cuts off the output current, in the event of a short or overload, by electronic switching. The short circuit protection switching time is of the order of 1 millisecond. Power supply operation is restored by simply turning the AC Power off and then on.
4. Automatic Adjustable Current Foldback (FB) provides an automatic current limit below which the current and compliance voltage will "foldback", linearly, to approximately 10% of the rated current as shown below. Narrow or "slot" range supplies often use this economical protection method which still allows operation into incandescent, capacitive or battery loads.



5. Fuse and Circuit Breaker Protection, although not generally used for output protection, is provided on all Trygon power supplies for AC power input protection.

11. MILITARY SPECIFICATIONS AND RELIABILITY

A. Mil Spec Power Supplies

The following chart indicates military specifications utilized in establishing the performance design criteria of standard Trygon supplies. Where required, Trygon can supply compliance data. Please contact the factory for details.

SPECIFICATION \ TRYGON SERIES	LABORATORY AND SYSTEMS POWER SUPPLIES											MODULES				
	HH	DL	HR	SHR	HR-B	RS	LR	M	C	SR	FT FTR	PS1	PS2	PS4	PHR8	PSD1
Quality Control MIL-Q-9858	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Temperature MIL-T-21200C(ASG)	S	S	S	S	S	S	S	S	—	S	S	S	S	S	S	S
Temperature MIL-E-16400 Class 4	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Temperature Shock MIL-E-5272C(ASG) Proc. 1	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Vibration MIL-T-4807A Method 1A	S	S	S	S	S	S	0	S	—	—	S	S	0	0	S	S
Shock MIL-E-4970A Proc. IV	S	S	S	S	S	S	0	S	—	—	S	S	0	0	—	—
RFI MIL-I-6181 Conducted & Radiated	S	S	S	S	S	S	S	S	—	—	—	S	S	S	S	S
RFI MIL-I-16910 Conducted & Radiated	S	S	0	0	0	0	0	—	—	—	—	S	S	S	0	0
RFI MIL-I-26600 Conducted & Radiated	S	S	S	S	S	S	S	S	—	—	—	S	S	S	S	S
RFI MIL-I-26600 Amend 10 Conducted & Radiated	S	S	0	0	0	0	0	0	—	—	—	S	S	S	0	0
Transformers MIL-T-27A Grade V, Class 3	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Wire MIL-W-16878D	S	S	S	S	S	S	S	S	S	—	S	S	S	S	S	S
Non-Fungus Nutrient Materials	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

S indicates standard performance feature

0 indicates optional performance feature

B. Reliability

Optimum reliability is guaranteed throughout the production phase, of Trygon power supplies, by strict adherence to the Quality Assurance procedures of MIL-Q-9858. Only quality components are used in the manufacturing process. Power transistors are hermetically sealed silicon types. Zener diodes are temperature stabilized. Electrolytic capacitors are computer grade with rated life in excess of 10 years. Transformers meet or exceed the requirements of MIL-T-27A. All standard Trygon power supplies carry a 5 year warranty.

Mean Time Between Failure (MTBF) analysis is conducted in accordance with MIL-HDBK-217. The table below is a typical MTBF analysis performed by Trygon. MTBF calculation tables, as well as test data sheets are available for every standard Trygon power supply and will be furnished upon request.

RELIABILITY CALCULATION FOR POWER SUPPLY Series 1 Module

PART DESCRIPTION	NUMBER OF UNITS PER SUPPLY (N)	ESTIMATED FAILURE RATE PER COMPONENTS* % FAILURE PER 1000 HRS. (λ)	ESTIMATED FAILURE RATE PER COMPONENT GROUP % FAILURE PER 1000 HRS. ($N\lambda$)
Silicon Diodes	7	.02	.140
Controlled Rectifiers	None	.05	—
Germanium Transistors	None	.025	—
Silicon Transistors	7	.025	.175
Composition Resistors	6	.001	.006
Power Wirewound Resistors	5	.04	.200
Metal Film Resistors	11	.02	.220
Paper Capacitors	2	.003	.006
Aluminum Electrolytic Capacitors**	4	.035	.140
Transformers	1	.06	.060
Motors	None	.55	—
Low Population Parts	1 set	.3	.300

Mean time between failure MTBF $= 1/\Sigma N\lambda = 80{,}300$ hours

$\Sigma(N\lambda) = 1.247$

Probability of survival for time T: $Ps = e - \Sigma(N\lambda)t$

Probability of operation for 2500 hours without failure:

$Ps = e^{-(1.247X10^{-5}X2500)} = e^{-.0312}$

$Ps = 96.9\%$

*Reference: Handbook Reliability Stress and Failure Rate Data for Electronic Equipment, MIL Hdbk 217, dated 8 August 1962. Values based upon actual derating factors.

**Computer Grade

C. Special Requirements

Standard Trygon power supplies can be modified to meet special requirements. Trygon's unique manufacturing techniques and wide selection of standard units provide a capability for producing special power supplies at nominal costs, thereby avoiding the need for custom built units with their attendent high cost and delay. Many power supply users depend on the field-proven reliability record of power supplies engineered and manufactured by Trygon.

REACTANCE CHART

Always use corresponding scales

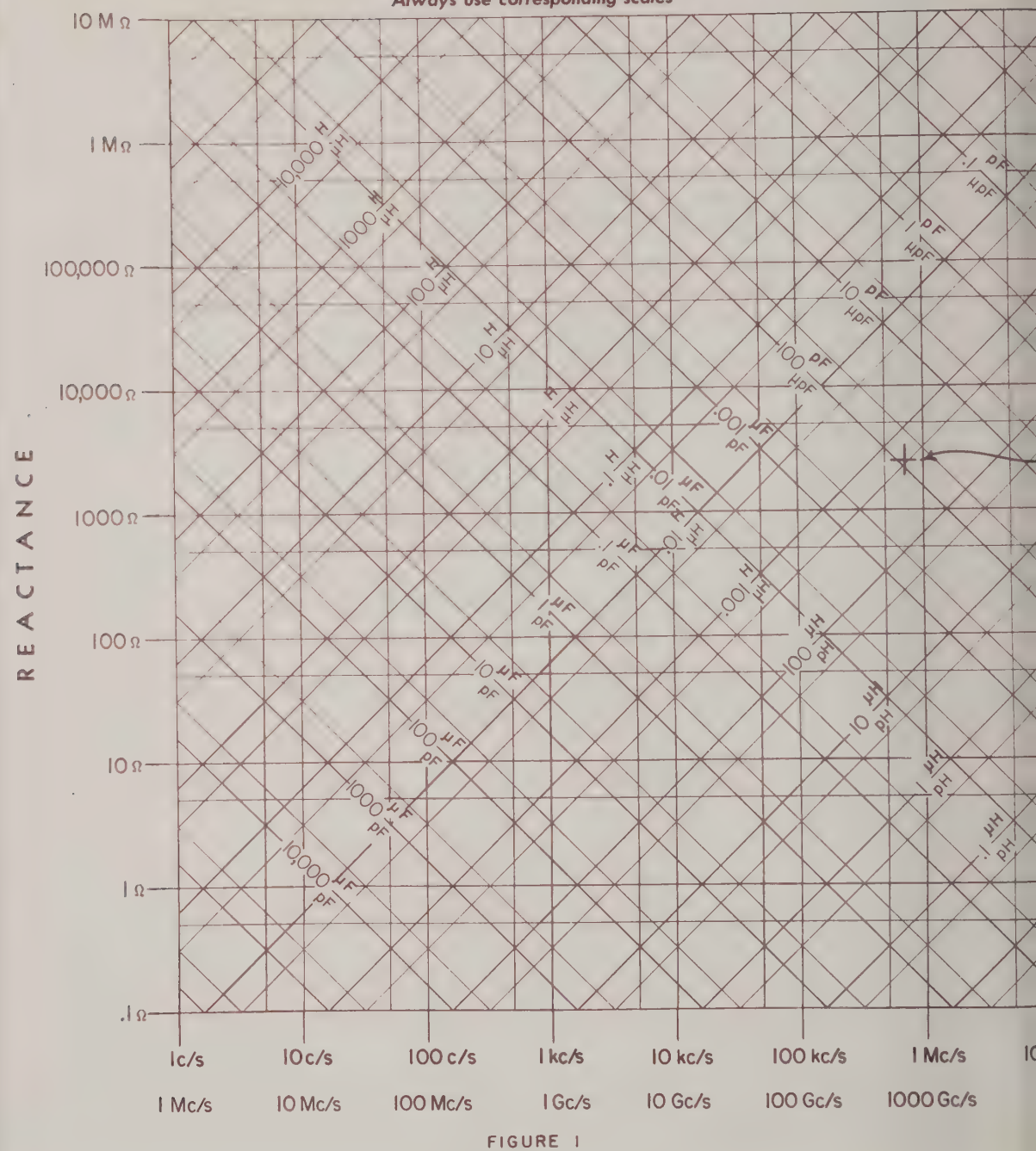


FIGURE 1

Figure 1 is the complete chart, used for rough calculations. Figure 2, which is a single decade of Figure 1 enlarged approximately 7 times, is used where two or three significant figures are to be determined.

TO FIND REACTANCE Enter the charts vertically from the bottom (FREQUENCY) and along the lines slanting upward to the left (CAPACITANCE) or to the right (INDUCTANCE). Corresponding scales must be used throughout. Project horizontally to the from the intersection and read REACTANCE.

TO FIND RESONANT FREQUENCY Enter the s ing lines for the given inductance and capacita Project downward and read resonant frequency the bottom scale. *Corresponding scales must be used throughout.*

REACTANCE CHART

Always obtain approximate value from Figure 1 before using Figure 2

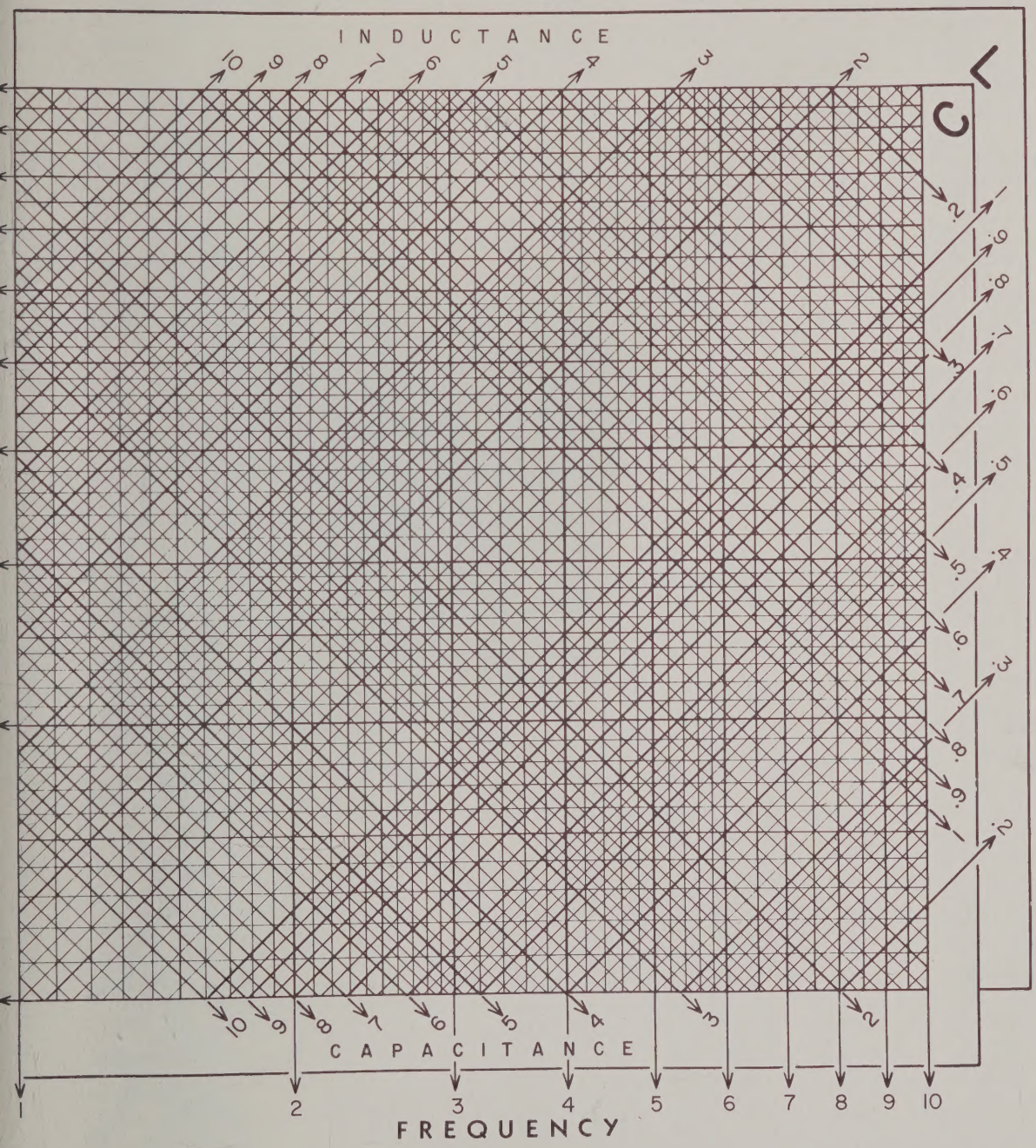


FIGURE 2

mple: The point indicated in Figure 1 corresponds to requency of about 700 kc/s and an inductance of μH, or a capacitance of 100 pF, giving in either e a reactance of about 2000 ohms. The resonant fre- ncy of a circuit containing these values of inductance capacitance is, of course, 700 kc/s, approximately.

E OF FIGURE 2 Figure 2 gives additional precision does not place the decimal point, which must be ated from a preliminary entry on Figure 1. Since the chart necessarily requires two logarithmic decades for inductance and capacitance for every single decade of frequency and reactance, unless the correct decade for L and C is chosen, the calculated values of reactance and frequency will be in error by a factor of 3.16.

Example: (Continued) The reactance corresponding to 500 μH or 100 pF is 2230 ohms at 712 kc/s, their resonant frequency.

Reactance Charts Courtesy General Radio Company, Concord, Mass.

GLOSSARY OF TRYGON TERMS

The terms used in Trygon's Power Supply Handbook are intended to be meaningful to Trygon Power Supply users. Until such time as technically significant terms are standard throughout the industry, those presented will describe the terms used in Trygon literature.

AUTOMATIC CROSSOVER:
The point at which the power supply operating mode automatically changes from constant voltage to constant current, or the reverse, as a function of variations in load conditions. Crossover is adjustable and can be established anywhere within the voltage/current range of the supply.

AUTOMATIC TRACKING OVERVOLTAGE PROTECTION (OV):
Electronic control circuitry which automatically tracks the programmed output voltage to prevent the supply output from rising above the programmed voltage for any reason. The cut-off point moves automatically with the programmed output voltage. (See Application Notes.)

CONSTANT CURRENT POWER SUPPLY:
A power supply which acts to maintain its output current constant despite changes in load resistance. These variations in load resistance are automatically compensated by a voltage change to keep the ratio E_o/R_{load} constant. (See Application Notes.)

CONSTANT VOLTAGE POWER SUPPLY:
A power supply which acts to maintain its output voltage constant despite changes in load resistance. These variations in load resistance are compensated by an automatic change in output current to keep the ratio I_o/R_{load} constant.

ERROR VOLTAGE:
The voltage developed in the regulating control circuits whenever the output departs in amplitude from pre-established values. This voltage is used by the regulating circuits to vary the output to bring it within the regulation band.

OUTPUT IMPEDANCE:
Power supply output impedance is the ratio of the change in output voltage to the change in load current. Usually expressed as nominal DC-1KC values.

PARALLEL OPERATION:
Connecting the outputs of two or more Trygon Power Supplies to obtain a higher current output than that obtainable from a single power supply. (See Application Notes.)

RECOVERY TIME:
The time in microseconds required for a power supply output to return to the output voltage level of the supply, plus or minus a specified voltage, after a specified step change in rated load; e.g., less than 50 microseconds to recover within 10 mv of output voltage for 100% step change in rated load.

REGULATION, LINE:
The maximum change in output, voltage or current, resulting from a step change in input line voltage. Expressed as a percentage of the output or in output units, e.g., millivolts.

REGULATION, LOAD:
The maximum change in power supply output resulting from a change in the load resistance over the range no load to full load. Expressed as a percentage of the output or in output units, e.g., millivolts.

REMOTE CURRENT PROGRAMMING:
An automatic method of remotely controlling the current output of a power supply. (See Application Notes.)

REMOTE PROGRAMMING SCALE FACTOR:
The change in programming resistance required for a specified voltage output change.

REMOTE SENSING:
The ability of the regulating circuitry to determine the actual voltage present at the remote load terminals and to compensate for any difference between that measure and the voltage at the power supply output terminals.

REMOTE VOLTAGE PROGRAMMING WITH RESISTANCE:
A method of remotely controlling the voltage output of a power supply by means of a remote resistive control element. (See Application Notes.)

REMOTE VOLTAGE PROGRAMMING WITH VOLTAGE:
An automatic method of remotely controlling the voltage output of a power supply by means of a remote variable voltage input.

RIPPLE:
The RMS value of AC components appearing in the power supply output.

SERIES OPERATION:
Connecting the outputs of two or more Trygon Power Supplies to obtain a higher voltage output than that obtainable from a single power supply. (See Application Notes.)

SERIES REGULATION:
A technique using variable impedance, usually active devices, in series with the power supply output. Variation in output from the pre-established value causes a variation in the series impedance to hold the power supply output constant.

SLAVING (Master):
Connecting two or more Trygon Power Supplies of the same output polarity so that the output level of all supplies is controlled by a master unit.

SLOT RANGE:
A specific narrow range of voltage output produced by a power supply; e.g. Trygon LR6-40, output voltage 5 to 7 volts.

STABILITY:
The change in output of the power supply current or voltage over a specified time interval after initial warm-up. Measured at constant line voltage, load and ambient temperature.

STORAGE TEMPERATURE:
The temperature range over which a non-operating supply may be stored or shipped without noticeable effect upon its operation after removal from storage.

TEMPERATURE COEFFICIENT (TC):
The change in output per incremental change in ambient temperature, usually expressed as a percentage/°C. e.g., 0.05%/°C, within the operating temperature range.

TEMPERATURE RANGE (AMBIENT TEMPERATURE):
The environmental temperature in which the supply will operate to its performance specifications. The temperature of the air at the intake side of forced air cooled units.

THERMAL OVERLOAD PROTECTION:
A control technique using a temperature sensor and appropriate control circuitry which monitors power supply temperature. Automatic shut-down of the supply occurs when a maximum safe temperature limit is reached.

TRACKING:
Connecting two or more Trygon Power Supplies together so that the positive outputs and negative outputs maintain a fixed relationship, once established.

TRANSIENT:
Any short duration amplitude-time change in the power supply as the result of a change of line or load.

TRYLINK PRECISION CURRENT REGULATION MODE:
A rear panel link connection, available on certain Trygon Power supplies, which adds a resistive element to provide precise line and load regulation in the current mode.

VOLTAGE COMPLIANCE:
The range of output voltage available to maintain a given current level, in the constant current mode.

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